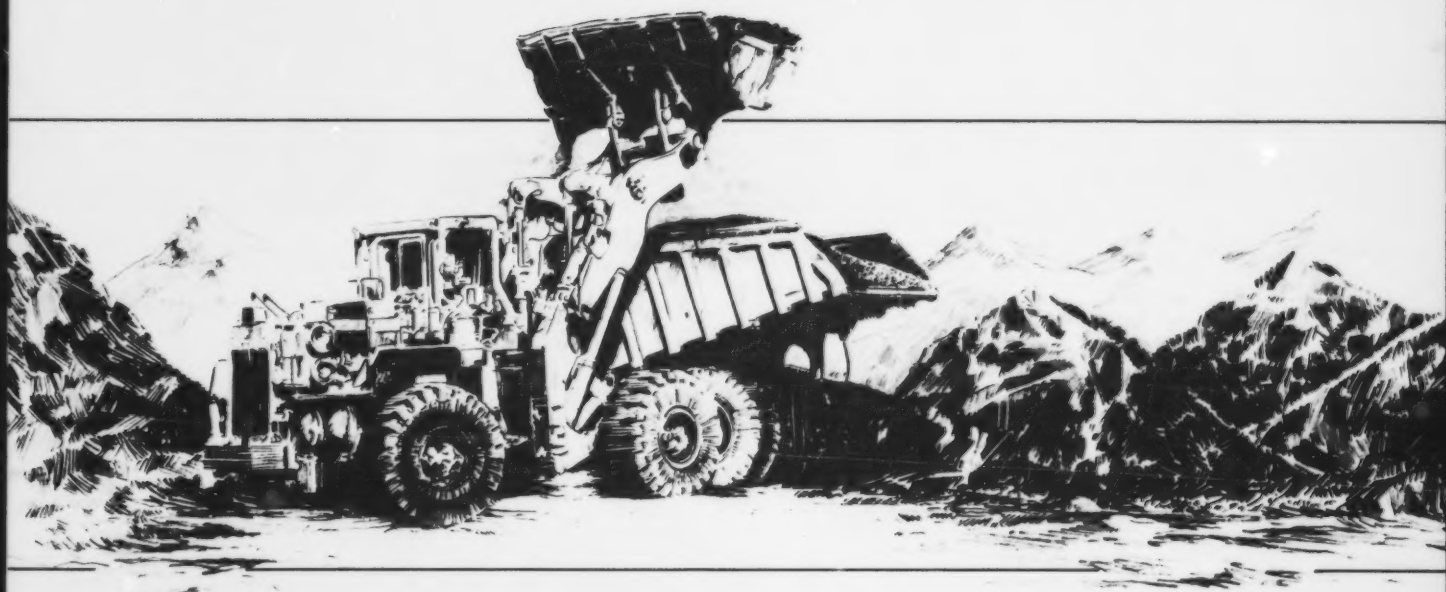


Coal in B.C.

An Assessment of
Future Prospects



by Richard T. Marshall
Resource Management Services

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Honourable Anne Edwards
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Ministry of Energy, Mines and Petroleum Resources
Parliament Buildings
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Dear Ms. Edwards:

I respectfully submit this report, "Coal in British Columbia: An Assessment of Future Prospects". The report is the result of extensive research into the British Columbia coal industry, including consultations with representatives of all the key stakeholders and participants in the industry. It includes a number of recommendations for your consideration.

The report is supported by additional detailed studies on the impact of changing technology on the demand for both coking coal and thermal coal. These studies are included as Appendices.

I understand the report will be used as a basis for further discussion with those interested in the coal industry, and that the recommendations will be reviewed in the context of developing strategic initiatives for the coal industry. I hope you will find this report informative and helpful in the process of developing these initiatives.

Sincerely,



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This report is intended to provide information and analysis on the issues surrounding the coal industry in British Columbia.

The conclusions and recommendations reflect the author's views only and do not necessarily reflect those of the Ministry of Energy, Mines and Petroleum Resources.



**COAL IN BRITISH COLUMBIA
AN ASSESSMENT OF FUTURE PROSPECTS**

PREPARED FOR

THE MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES

BY

**RICHARD T. MARSHALL
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DECEMBER, 1991

Graphics, Graphic Design and Type Setting
by
By Design Services

1. FOREWORD

This report, "Coal in British Columbia: An Assessment of Future Prospects", was commissioned by the Ministry of Energy, Mines and Petroleum Resources.

It was recognized that the coal industry in the province was facing some serious issues. There was a need to have these issues analyzed and to develop recommendations which could guide a future course of action.

The objective of the study was to assess the current conditions and future prospects for British Columbia's coal industry, and to identify ways in which the industry's contribution to the province's economic, social and environmental goals can be enhanced consistent with maintaining and improving the international competitiveness of the industry.

A small project team of government and private sector persons was assembled to undertake this program and to develop recommendations. The author wishes to express his appreciation to those Canadian coal companies who so generously provided their views and information on the coal industry, and to all who so freely gave of their time and helpful assistance in compiling this study.

It is hoped that the recommendations provided will assist the government in the development of a policy framework which will recognize provincial environmental and social objectives while ensuring that coal remains a vital component of British Columbia's economy.

Coal In British Columbia
An Assessment Of Future Prospects
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3. EXECUTIVE SUMMARY AND RECOMMENDATIONS

British Columbia produces some 25 million tonnes of coal per year from eight mines located in three geographical regions. Of this, 95 per cent of the coal is consumed outside the province and mostly outside Canada, mainly in the Pacific Rim. About 36 per cent of Canada's total coal production originates in British Columbia; however, the province represents 78 per cent of Canada's metallurgical coal exports and about one half of the thermal coal exports. These results have been achieved despite British Columbia's harsh winter climate and long transportation distances between the mines and the ports.

This activity provides gross revenues to the provincial mining companies of \$1.6 billion annually and further revenues are generated within the province in the transportation and terminalling of other Canadian coals destined for the export market via British Columbia.

In terms of gross revenue generated, coal exceeds all other individual mineral commodities, and for many communities it constitutes their primary revenue base. There is no doubt that coal is an important component of British Columbia's economy.

It must be remembered that even though coal is one of the world's largest sources of energy, it is a commodity. Like most commodity businesses, coal is cyclic in nature. Outside influences, largely beyond the control of individual companies, can have a major impact on profitability. Some of these relate to the supply-demand situation, world coal prices and government policies, including monetary policies and subsidization. Inasmuch as the provincially based mines are dependent on the international market place, they are left vulnerable to these factors.

The coal industry carries a high risk because of the long time lag between capital investment and financial return. Not only is it capital intensive, but the time between initial

investment in reserve acquisition through development, production and first revenue, stretches over many years.

From the production standpoint, the province's coal industry rates as one of the best in the world, using the latest technologies, innovative implementation of these technologies, a skilled work force, a highly reliable and efficient transportation system, and some of the most modern coal terminals in the world capable of handling the largest ships. The industry has overcome technical challenges of mining in mountainous terrain and has learned to compete in the world market even with much longer inland rail hauls than our major competitors, Australia and South Africa, have to contend with.

During the post second world war years, demand for steel in Japan was growing by leaps and bounds. To satisfy this requirement, the Japanese constructed the most modern steel mills in the world. In order to raise foreign currency Japan started exporting quality steel and was soon one of the largest and most modern steel suppliers in the world.

To meet the requirements of raw material supply for their steel industry, Japan commenced seeking reliable sources of iron ore and coal. During the 1960s and early 1970s, Canada and Australia responded to this market situation. Both of these countries had large reserves of good quality metallurgical coal with only modest domestic requirements. Coal shipments commenced from existing mines, but the largest volumes originated from new mines. Considerable capital was invested in each country by both industry and governments to develop these new mines and the associated infrastructure.

Japan very quickly became the world's largest importer of coal and Canada along with Australia were its largest suppliers. Demand for steel continued to grow and supply of coal was

barely able to keep up with demand. Japan, having limited indigenous resources, was becoming increasingly dependent on external sources. Therefore in the 1970s Japan, based on its forecasted demand, once again embarked on an aggressive coal purchasing program. For a number of reasons, one being security of supply, and a second the objective of trying to maintain favourable pricing arrangements, the Japanese contracted more coal than they required.

British Columbia coal producers responded to this growing market for coal and during the early 1980s, the industry invested over \$2.0 billion of additional capital in the expansion of existing mines and the development of five new mines, increasing annual production capacity by 14.9 million tonnes. At the same time the provincial and federal governments invested over \$1.5 billion to provide infrastructure for this new production capacity.

Coal demand was also growing in Europe and as a result they began importing substantial volumes of coal to supplement their domestic production. Korea and Taiwan were also building new steel mills in the late 1970s and early 1980s and they too were acquiring long term supplies of coal. The Japanese, however, because of their dominant position, became the price setters in the seaborne coal trade.

In 1982 a world wide recession occurred. As a direct consequence, the demand for steel did not reach the levels anticipated. Indeed, even now it has not reached the levels some analysts were predicting. Demand for coal in the consuming countries could not keep pace with the installed production capacity around the world. This situation was further aggravated by the fact, as mentioned previously, that Japan had overcontracted supply requirements. World steel producers also had an overcapacity. As a result, steel prices declined. The Japanese mills did not escape this situation and looked to coal suppliers to share some of the burden in reducing production costs of steel. The coal producers had made substantial investments in mine development and had long term supply contracts. Therefore it was in their interest to keep the new mines operating. The Japanese steel mills, through their astute purchasing practices and dominant, oligopsonistic, purchasing power, having thoroughly evaluated each

producer's costs, were able to set prices marginally above those costs.

The British Columbia coal producers were fully exposed to the impacts of this situation. The fact that over 95 per cent of the coal produced is exported leaves the industry in the province particularly vulnerable to the vagaries of the coal market place. In this market, product supply and demand, and ultimately prices, are shaped by global economic forces, which are largely beyond the control of any one supplier but not necessarily beyond a cohesive group of buyers.

Towards the end of the 1980s demand for coal started to rise once again and total volumes of coal produced continued to increase. In British Columbia this high level of production is offset by continuing low prices and increasing costs resulting in dismal financial returns to the industry. This resulted in drastic actions being taken.

During 1990 Esso Resources Canada Limited placed Byron creek Collieries on the market. This action has not led to a completed sale and the mine which is currently maintaining the supply of coal to its principal customers, faces the possibility of closing when these contracts expire in 1992.

Crows Nest Resources Limited recently announced the sale of their Line Creek Mine to Manalta Coal Ltd.

In March 1991 Teck Corporation made arrangements with Denison Mines Ltd. to take over the operations of Quintette, currently operating under protection of the courts.

All of these situations confirm the fact that the B. C. coal industry is experiencing problems that must be addressed now. There is a genuine concern about the overall competitiveness of the industry largely due to factors beyond its control.

One must be careful in dealing with an industry as a whole, it is easy to create misconceptions. Each mine has its own set of unique circumstances which can affect profitability. Needless to say there are some operations in the province that are operating quite effectively under present conditions and which are in the business for the long term. However, if one or two mines should close, which must be considered a possibility, such event would result in a domino effect that could have negative impacts on remaining mine operations.

In any event, the current economic climate for coal mining in British Columbia is not healthy; there are too many operations that are today only economically marginal and in the interests of British Columbia, this situation must change. It was for this reason the province commissioned this study to assess current conditions and the future potential of the industry in order to develop a strategy for the future.

In the short term there may be some easing of demand for metallurgical coal in 1991 with a corresponding reduction in sales. Prices for thermal coal will remain soft and Canadian suppliers will only meet their market commitments, but there will be no increase in thermal coal exports until prices warrant increased participation.

In the longer term, overall coal demand will grow substantially. Most of this growth will be for thermal coal to satisfy the requirements of a growing world population with increased demands for electricity.

A number of forecasts have been made through to the year 2010. On the basis of western world imports of coal alone volumes will grow from 379 million tonnes in 1990 to 709 million tonnes in 2010 at median levels. (Table 3.1)

Table 3.1 Forecasted World Coal Import Requirements 1990 to 2010 (millions of tonnes)					
	1990	1995	2000	2005	2010
High	378.4	455	538	653	729
Low	378.4	421	499	605	690
Median	378.4	437	518	629	709

With respect to metallurgical coal new technologies in steel making will influence the markets for B. C. coal. The increased use of pulverized coal injection (PCI) will reduce the required volumes of high quality coking coal, the type produced in B. C., used to make coke for the blast furnace. The PCI process reduces the amount of coke required which is replaced by injecting a lower quality, less expensive, coal into the furnace.

The Japanese are leading the way in adopting this technology and to indicate the impact

Table 3.2 shows the reduction in hard coking coal required for coke manufacture in Japan through 2010. This reduction is offset by an increase in demand for PCI coal of 12 million tonnes per year by 2010.

Table 3.2 Forecasted Japanese Consumption of Imported Metallurgical Coal For Coke Manufacture 1990 to 2010 (millions of tonnes)					
	1990	1995	2000	2005	2010
High	61.4	62	55	50	46
Low	61.4	30	22	14	10
Median		45	38	32	28

The overall forecast for metallurgical coal through to 2020 including both coking coal and PCI coal, on an import requirement basis show a drop from 170 million tonnes per year in 1990 to 146 million tonnes per year in 2010. (Table 3.3)

Table 3.3 Forecasted Western World Consumption of Imported Metallurgical Coal and PCI Coal 1990 to 2010 (millions of tonnes)					
	1990	1995	2000	2005	2010
High	170	179	177	179	166
Low	170	145	138	131	127
Median		161.5	157	155	146

World demand for thermal coal is on the threshold of a major expansion. The forecasted growth in the western world's import requirements show an increase from 208 million tonnes per year in 1990 to 563 million tonnes per year in 2010 (Table 3.4)

The Pacific Rim has one of the fastest growing requirements for thermal coal. Repeating the successful metallurgical coal procurement strategy, Japan is playing a major role in setting market forces by encouraging new production in Indonesia thus influencing prices from other sources.

Table 3.4
Forecasted
World Thermal Coal Imports
1990 to 2010
(millions of tonnes)

	Europe	Asia	Latin America	North America	Total
1990	116	78.5	1.3	12.6	208.4
1995	155	110	2.0	9.0	276
2000	191	152	4.0	14.0	361
2005	265	185	7.0	17.0	474
2010	315	214	12.0	22.0	563

The long term total demand for coal is strong; however, as indicated in the foregoing, the market is changing. The net result will be increased market coupled with increased competition. In order to maintain current market share for metallurgical coal, British Columbia producers will have to increase their competitive edge. At the same time they will have to become more aggressive in exploring opportunities in the thermal coal trade.

Concerns about the use of coal for generating electricity persist in the minds of the public. These concerns are normally based on a lack of understanding of current technologies available in Canada and images from parts of the world where these technologies are not utilized. Current and new technology can alleviate these concerns, the problem being to get this message across to the public.

Factors that affect the profitability and competitiveness of the British Columbia coal producers are:

- A coal price that is too low to enable adequate returns on capital invested.
- Canada's monetary policy of maintaining high interest rates resulting in an unfavourable exchange rate for coal exported in U.S. dollars.
- An oversupply situation with installed production capacity in excess of current world demand.
- The forecast demand for coal has not grown at the rate or by the volume predicted in the 1970s. and early 1980s.

- Japanese domination of the world seaborne coal trade resulting in their becoming price setters.
- Increased levels of taxation at the municipal, provincial and federal levels.
- Increasing labour costs.
- Fuel taxes on rail transportation of coal.
- Production subsidies and other direct government assistance provided on coal production in the EEC and Japan.
- Federal/provincial regulatory policies that result in duplication of effort and costly delays in gaining project approvals.

The purpose of this study is to review the state of the coal industry in British Columbia, assess future prospects and provide recommendations that will assist the producers in expanding their trade, bring increased stability to mines and communities and maintain the high standard of environmental protection.

Although the industry is experiencing difficulties at the present time, there is no infusion of large sums of government funding required. Certain courses of action the government can take have been identified. These actions will assist the coal industry to compete in the international market and develop new trade.

The provincial government should:

- Develop a long term strategy for coal.
- Publicly acknowledge the important role coal plays in the provincial economy.
- Undertake a program to educate the public which would illustrate that coal, by utilizing current and new technologies, can be used safely and cleanly without causing irreparable damage to the environment.
- Evaluate the opportunity to create a domestic market for coal within the province by complementing the existing hydroelectric generating capacity with coal fired thermal generating plants.
- In the short term, expedite the review process with respect to proposed small thermal generating plants in southeast British Columbia.

- Continue to monitor the development of the IGCC process for electric power generation.
- Consider participation in some manner in an out-of-province IGCC demonstration plant.
- Deliver a strong message to the Japanese steel industry, in turn Japan, concerning the impacts of their present pricing policies.
- Renew provincial efforts to address federal monetary policies.
- Bring increased pressure through GATT on EEC and other countries to eliminate the practice of coal subsidies.
- Create an inter-ministry team to review the tax burden on the coal industry, including railways and coal terminals:
 - Harmonize provincial/federal sales taxes.
 - Property tax.
 - Mineral tax.
- Take prompt action to resolve the jurisdictional dispute between the federal and provincial departments of environment to alleviate duplication of effort, unwarranted additional expense and costly delays.
- Recognizing the growth in world demand for thermal coal, develop a program through the provincial Geological Survey Branch to define the potential of the British Columbia coal resources as a source of thermal coal.
- Develop a mechanism whereby the southeast coal communities are better informed of one another's capital programs and accept the offer from industry to discuss the impact of proposed programs prior to approval.
- Through the Department of Municipal Affairs, monitor and if necessary re-evaluate the southeast coal communities' Industrial Tax Sharing Agreement to ensure equitable treatment for all communities.
- Examine immediate rebate of all outstanding Workers' Compensation Fund over-payments.
- Ensure provincial trade missions have current and factual information on the coal industry and where possible, invite industry to participate. Missions must focus on their objectives.
- Investigate bi-lateral agreements that may present the opportunity to use provincial coal mining and environmental expertise abroad.
- Monitor clean coal technology development and support coal research and development where and when appropriate.
- The government should undertake an investigation of the economic potential for developing a coke plant in the province. Coal companies should be invited to participate.

A report prepared for the British Columbia Round Table On The Environment And The Economy* concluded that when inter-industry linkages are taken into account, natural resource industries are found to be drivers of the provincial economy with significant employment benefits in other sectors. The export sector accounts for a 37 per cent contribution to the GDP (gross domestic product, as measured by expenditures). This result implies that the provincial economy continues to be heavily reliant on natural resource industries.

With the correct political climate and sound economic policies the coal industry will continue to make a substantial contribution to the economy of the province at the same time achieving environmental objectives.

The character of the industry will change as it responds to changing market requirements. The province has a good resource in coal and an efficient, highly technical mining industry. There is little doubt coal will continue to play an important role in the future of the province.

* The Structure of the British Columbia Economy: A Land Use Perspective: Prepared for the British Columbia Round Table on the Environment and the Economy by the Ministry of Finance and Corporate Relations, March 1991.

4. INTRODUCTION

The province of British Columbia has extensive reserves of coal of all varieties the predominate of which is bituminous coal produced for use in the steel making industry. Thermal coal is also produced and is used mainly for generating electricity.

Canada ranks tenth in the world in terms of coal production of which roughly one half is exported. It is this export market that resulted in the massive development of coal in British Columbia during the last two decades. Almost all of the province's coal is destined for export, thus the industry is highly dependent on international markets and is fully exposed to the vagaries of the supply-demand ramifications of the international marketplace. The new and expanded industry of the 1980s was thrust into a period of economic difficulty due to a downturn in steel demand

resulting in an oversupply of world coal between 1986 and 1988. Even though this situation eased in 1989-1990, the industry has not fully recovered from the impact of rising costs and lower prices. The producers are not generating adequate financial returns on the funds invested and are now faced with making many difficult decisions.

There is a growing concern that some provincial coal producers may not be able to maintain their competitive position in the world market and this could lead to possible mine closures.

This report presents a complete review of the British Columbia coal industry including its history and the outlook for the future. It also contains a number of recommendations for the government to consider that will assist the industry in maintaining its contribution to the economic and social objectives of the province.

5. HISTORY OF COAL MINING IN BRITISH COLUMBIA

Coal mining in British Columbia commenced on Vancouver Island during the mid 1880s. From that time forward, the industry has gone through a number of economic cycles. Even with these repeated cycles, the industry has continued to grow and to respond as best it could to changing circumstance. Needless to say, after each coal downturn, the industry which re-emerged was somewhat different in character and, in most instances, more technologically advanced.

What took place in the coal industry in British Columbia was in many ways a reflection of the coal industry in Canada as a whole. For instance, beginning during the 1880s and continuing through and after the second world war, most coal produced in Canada was from labour intensive underground coal mines. Following the discovery of vast quantities of oil in Alberta in 1947 and the consequence of the railways converting from coal-fired steam engines to oil-fired diesel engines, the industry all but disappeared.

When the industry re-emerged in the late 1960s, coal was produced from large scale surface mines with less than ten percent of the total production originating from the underground mines.

This resulted in fewer mines producing greater volumes of coal. Although the industry tends to continue to be fairly labour intensive, through new technologies the annual output per worker has increased significantly.

Table 5.1 best demonstrates how the character of the industry changed between 1948, the peak in annual coal production prior to the impact of low cost oil and gas, and 1989.

The resurgence of the coal industry in the 1960s was brought about by two significant events; firstly, the growing demand in Alberta and Saskatchewan for low sulphur coal to fire on-site thermal electric generating stations and secondly, the increasing demand for coking or metallurgical

Table 5.1

Canadian Coal Production 1948 Compared to 1989

	1948	1989
Annual production (millions of tonnes)	29	70.5
Number of employees	24 000	11 500
Tonnes per worker	1 208	6 130
Number of mines	360	27
Underground	340 approx.	6
Surface	20 approx.	21
Number of producing companies	340	11

coal to feed the rapidly growing Japanese steel industry.

It was this latter event that triggered the re-birth of the coal industry in British Columbia. During the mid 1960s the Japanese were desperate for good quality coking coal and were undertaking a very aggressive purchasing program. This program resulted in two large scale mines being developed in the southeast coal fields of the province, namely Kaiser Resources Ltd. (now Westar Mining Ltd.) with the Balmer mine located at Sparwood; and Fording Coal Ltd. with the Fording River Mine located some 48 km to the north of Balmer in the Fording River Valley. The Fording mine required the development of a new town site, Elkford, and the construction of a branch line of the Canadian Pacific Railway to service the mine.

Simultaneously with the development of these two mines was the construction of a huge

super port located at Roberts Bank near Vancouver. This port, operated by Westshore Terminals Ltd., became the largest bulk handling terminal in Canada.

The Canadian railways implemented the concept of unit train haulage of coal whereby complete train sets are dedicated to the exclusive use of moving coal from the mine to the port. These trains both load and unload on the move and return empty as a complete unit to the mine for another load of coal. Other than for maintenance, unit trains are continuously on the move. The use of unit trains, pioneered for the coal industry, has greatly reduced the cost of hauling bulk commodities.

In the ensuing years British Columbia coal producers diversified their markets for metallurgical coal to include Korea, Taiwan, South America and Europe. Today B. C. coal is shipped to some twenty-two different countries around the world.

In addition to supplying metallurgical coal into the world market, one mine, Byron Creek Collieries Ltd., was developed to supply thermal coal used for electric power generation. Their customers are in Canada and abroad. As the market for thermal coal offshore continued to grow, the metallurgical coal mines, when they had the ability to do so, also participated in this market with some of their higher volatile coals.

The demand for inter-continental trade in coal continued to increase and additional coal mines were developed to supply this growing demand. In addition, the Balmer and Fording River operations were expanded.

New mines brought on stream in the early 1980s included Westar's Greenhills Mine and Crows Nest Resources Limited's Line Creek Mine located in the southeastern coal fields; Teck Corporation's Bullmoose Mine, and Quintette Coal Limited's Quintette mine. These latter two mines are located in the northeastern coal fields and required new infrastructure to be put in place including the new town site of Tumbler Ridge, a

branch line of the British Columbia Railway, upgrading of Canadian National's railway from Prince George to Prince Rupert and a new bulk coal terminal at Ridley Island near Prince Rupert. Neptune Terminals, located in Vancouver's inner harbour, was expanded to handle the increasing volumes of coal going off-shore. One new thermal coal mine was developed during the 1980s on Vancouver Island. This was Brinco Coal Corporation's Quinsam Mine near Campbell River.

During the 1970s and early 1980s, numerous companies undertook extensive coal exploration programs in the province, resulting in many good development prospects being identified. Many of these prospects have advanced to the point where they are now waiting for the right market conditions to proceed with development.

In 1982 the world went into a recessionary period which resulted in a severe oversupply situation being created in the seaborne coal trade. This also resulted in price reductions to the extent that there were numerous mine closures in many countries. Canada was the exception in that no coal mines were closed during the 1980s. However, the Canadian mines experienced considerable hardships in coping with the reduced prices for their products and one company went to arbitration over a pricing dispute.

These events led to reductions in employment and periodic extended vacation shutdowns while at the same time significant productivity increases were achieved. Those companies supplying goods and services to the coal industry also suffered as a consequence of this recession.

In spite of these difficult times, the production of coal continued to increase through 1990 when some 25 million tonnes were produced. Nevertheless, some mines were finding it difficult to generate sufficient income to remain profitable at these depressed prices and international competitiveness was being threatened. Other producers were fairing better but all were suffering from reduced profit margins.

6. THE COAL RESOURCES OF BRITISH COLUMBIA

The province of British Columbia is generously endowed with coal resources. These coals, when classified by rank, include reserves of lignite, sub-bituminous, bituminous and anthracite coal. British Columbia is the only province in Canada to have reserves of anthracite available for mining and is indeed the only province with deposits of coal ranging in rank from lignite through to anthracite.

Generally speaking coals can be divided by use into two categories in that they are either consumed to generate heat as in the raising of steam for electric power generation or by carbonization to produce metallurgical coke for use in the steel making process. Coals which are used as a fuel for electric power generation or for raising heat for other industrial applications are referred to as "thermal" coals. Coals which are used in the production of metallurgical coke are referred to as "metallurgical" or "coking" coal.

As can be seen by referring to Table 6.1, the metallurgical coals are always bituminous coals and normally fall into the low to medium volatile group. Coal for electric power generation can range anywhere from lignite to high volatile coals.

It should be noted that the higher the rank or group of coal, the higher the heat content as measured in B.T.U.s per pound (btu/lb) or mega joules per kilogram (MJ/kg). Thus those coals with the higher heat content per unit of volume are able to stand transporting greater distances, a major factor in marketing.

The coal reserves of the province are shown on Table 6.2. On a recoverable basis, British Columbia possesses 89 percent of Canada's medium and low volatile coals the most desirable for coking purposes.

Not included in Table 6.2 are the extensive coal resources in the Groundhog and Bulkley River coalfields where substantial volumes of anthracite occur, along with an attractive prospect for thermal coal export, namely the Telkwa deposit (Table 6.3).

Of the total recoverable coal resources of Canada (Romaniuk and Naidu 1987) measured at 6 610 million tonnes, British Columbia ranks first by volume at 39 percent of the total followed by Alberta at 30 percent.

A detailed description of the coalfields in British Columbia has been developed by the Coal Resources Unit of the Geological Survey Branch of Energy Mines and Petroleum Resources. This report is included as Appendix C.

TABLE 6.1
CLASSIFICATION OF COALS BY RANK

VM%	FC%	CLASS	GROUP	CALORIFIC VALUE		PRINCIPAL USES
				BTU/lb.	MJ/kg	
2	98	ANTHRACITIC	META-ANTHRACITE			Space heating
8	92		ANTHRACITE			Chemical production
14	86		SEMI ANTHRACITE			
		BITUMINOUS	LOW VOLATILE BITUMINOUS			Metallurgical coke production
22	78		MEDIUM VOLATILE BITUMINOUS			Cement production Thermal electric power generation
31	69		HIGH VOLATILE A BITUMINOUS	14 000	32.6	
			HIGH VOLATILE B BITUMINOUS	13 000	30.2	
			HIGH VOLATILE C BITUMINOUS	11 500	26.7	
		SUBBITUMINOUS	SUBBITUMINOUS A	10 500	24.4	Thermal electric power generation
			SUBBITUMINOUS B	9 500	22.1	Conversion to liquid and gaseous petroleum substitutes
			SUBBITUMINOUS C	8 300	19.3	
		LIGNITIC	LIGNITE A	6 300	14.7	Thermal electric power generation
			LIGNITE B			Char production Space heating

Source: Coal Resources of Canada, G. G. Smith
Geological Survey of Canada Paper 89-4

TABLE 6.2

Estimated Coal Reserves of British Columbia
(compared to the rest of Canada)

Province	Predominant Rank*	Coal in Mineable Seams	Recoverable Coal
British Columbia (coalfield)		(million tonnes)	
Nanaimo	hvb	3	2
Comox	hvb	50	43
Hat Creek	lig-sub	739	566
Fernie/Flathead	m-lvb	540	436
Elk Valley	m-lvb	1 133	1 069
Peace River	m vb	710	476
Subtotal British Columbia	m-lvb	2 838	1 981
	hvb	19	17
	lig-sub	739	566
Alberta			
Subtotal Alberta	m-lvb	581	240
	hvb	1 033	800
	lig-sub	1 287	87
Saskatchewan			
Subtotal Saskatchewan	lig	2 088	1 670
New Brunswick			
Subtotal New Brunswick	hvb	28	21
Nova Scotia			
Subtotal Nova Scotia	hvb	570	415
TOTAL CANADA	m-lvb	2 964	2 221
	hvb	1 695	1 281
	lig-sub	<u>4 114</u>	<u>3 108</u>
		8 773	6 610

(Source: Romaniuk and Naidu 1987)

*Rank

m-lvb = medium to low volatile bituminous coal
 hvb = high volatile bituminous coal
 lig-sub = lignite and subbituminous coal

TABLE 6.3
COAL RESOURCES OF INTEREST
NORTHERN INTERMONTANE BRITISH COLUMBIA

Coalfield/Deposit	Predominant Rank	Measured	Indicated (million tonnes)	Inferred
Groundhog				
Mt. Klappan				
Evans Creek				
Panorama				
Groundhog	lvb-an	100	500	1 000
Bulkley River				
Telkwa				
Zymoetz				
Morice				
Kispiox				
Seaton				
Kathlyn Lake	h-mvb	30	50	100
TOTALS	lvb-an	100	500	1 000
	h-mvb	30	50	100

Estimated coal resource quantities are based mainly on information from the British Columbia Geological Survey Branch (W. Kilby, pers. comm., 1987), Dolmage Campbell and Associates Ltd. (1975), and MacKay (1947). Coal resource information for separate deposits is often proprietary and confidential and, therefore, only totals by coalfield are shown.

(Source: Coal Resources of Canada, G. G. Smith, GSC Paper 89-4)

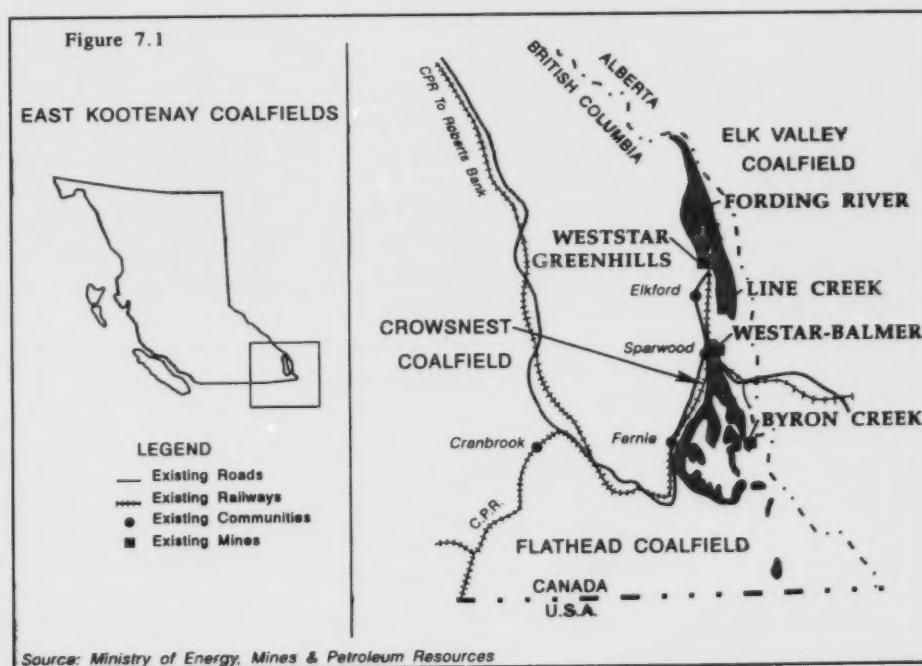
7. COAL PRODUCTION IN BRITISH COLUMBIA

Coal production in British Columbia originates from eight mines operated by seven companies. These mines are located in three distinct geographical regions, southeast British Columbia, Northeast British Columbia and Vancouver Island.

Commencing in the southeast, five mines operate in the Crowsnest and Elk Valley coalfields (Figure 7.1) of the East Kootenays.

coal is shipped offshore to the Pacific Rim. (Ownership of mines is shown in Table 7.1, on page 25)

Westar Mining Ltd. operates the Balmer Mine which is also located in the Crowsnest coalfield at Sparwood. Production has decreased from 6.0 million in 1989 to 5.6 million tonnes in 1990. Slightly less than 5.0 million tonnes are metallurgical with soft coking and thermal coal

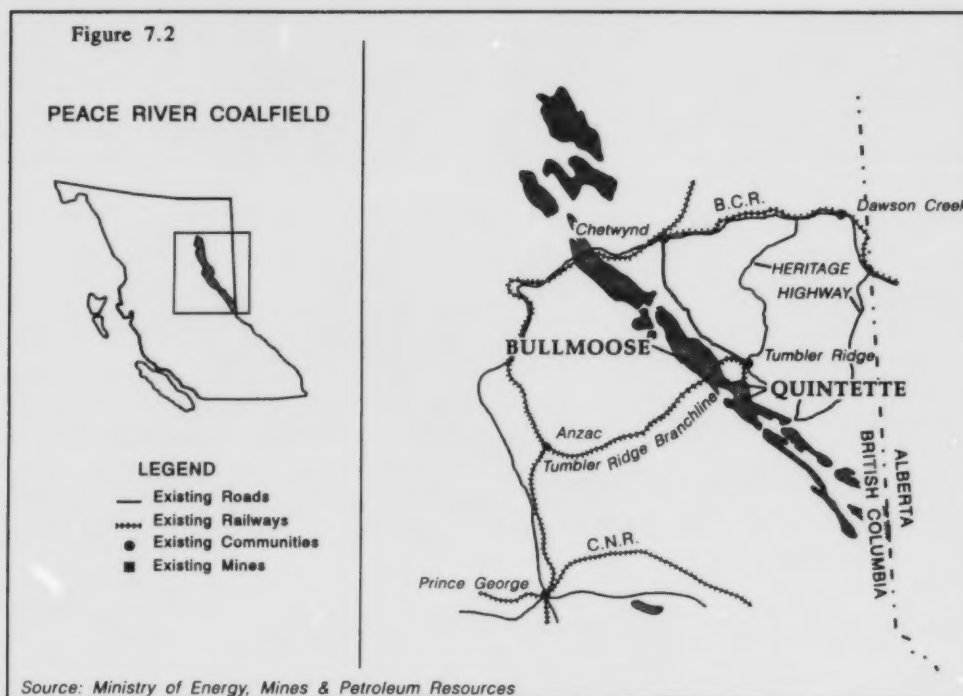


Byron Creek Collieries mines coal at Coal Mountain in the Crowsnest coalfield. Current production is in the order of 1.5 million tonnes of coal annually with most of the production thermal coal for use in Ontario, Manitoba and British Columbia. Thermal coal and some soft coking

providing the balance. About 98 percent of the sales are offshore with Japan being the largest customer.

Proceeding north into the Elk Valley coalfield, the next mine is Line Creek Resources Limited's Line Creek Mine.

Figure 7.2



Coal production is a little better than 2.0 million tonnes per year. Line Creek produces both metallurgical and thermal coal; however, thermal coal production is not consistent as it is tied to production of the metallurgical coal. It is for this reason Line Creek purchases coals from other sources for blending purposes. The major markets are in the Pacific Rim, Europe and South America. The Line Creek Mine commenced production in 1983.

The next mine in line, proceeding up the Elk Valley, is the Greenhills Mine operated by Westar Mining Ltd. The major markets are in Korea, Europe, Taiwan and Japan. Production levels reach 3.0 million tonnes per year of metallurgical, thermal and soft coking coal. Metallurgical coal dominates the sales, representing 88 percent of the total. Production commenced at Greenhills in 1983.

The most northerly mine in the Elk Valley coalfield is the Fording River operations of Fording Coal Limited. Production began in 1970 and has continued to increase to current levels of 6.3 million tonnes per year. Typically, most of the

production is destined for the steel mills, although thermal coal is also produced. Major markets include Japan, Korea, Taiwan, South America, Europe and the U. S. A. Thermal coal is also supplied to customers overseas and in North America.

Two mines operate in the Peace River coalfield (Figure 7.2), namely Quintette and Bullmoose.

Quintette Coal Limited, operated by the Teck Mining Group, is the largest producer of metallurgical coal in northeastern British Columbia, with a production capacity of clean coal at 6.3 million tonnes.

Production of clean coal in 1990 was 4.6 million tonnes, the bulk of which was destined for Japan. Quintette had 1 320 employees in 1990.

The Bullmoose Mine is operated by Teck-Bullmoose Coal Inc. The mine which is located 35 km north of the town of Tumbler Ridge produces 1.6 million tonnes of metallurgical coal for the Japanese steel mills.

TABLE 7.1

OWNERSHIP of BRITISH COLUMBIA COAL MINES

MINE	OWNERS	OWNERSHIP (%)
Byron Creek	Esso Resources Canada Ltd.	100.0
Balmer	Westar Mining Ltd.	
	B.C. Resources Corporation	66.6
	Mitsubishi Corporation & Nine Japanese Steel Companies	33.4
Line Creek	Line Creek Resources Ltd. Manalta Coal Ltd.	100.0
Greenhills	(Joint Venture)	
	Westar Mining Ltd.	80.0
	Pohang Iron & Steel Co. Ltd. (Korea)	20.0
Fording	Fording Coal Ltd. Canadian Pacific Investments Ltd.	100.0
Quintette	Quintette Coal Ltd.	
	Denison Mines Ltd.	50.0*
	Mitsui Mining Overseas Development Co.	12.5
	Charbonnages de France International	12.0
	Tokyo Boeki Ltd.	10.5
	Sumitomo Corp.	5.0
	Eight Japanese Steel Companies & Mitsubishi Chemical	10.0
Bullmoose	Teck Corp.	61.0
	Lornex Mining Corp.	29.0
	Nissho Iwai	10.0
Quinsam	Brinco Coal Corporation	100.0
*	These shares, by right of first refusal, are available to the remaining shareholders. Those shares not purchased will then be made available to Teck Corp. on a pre-arranged basis.	

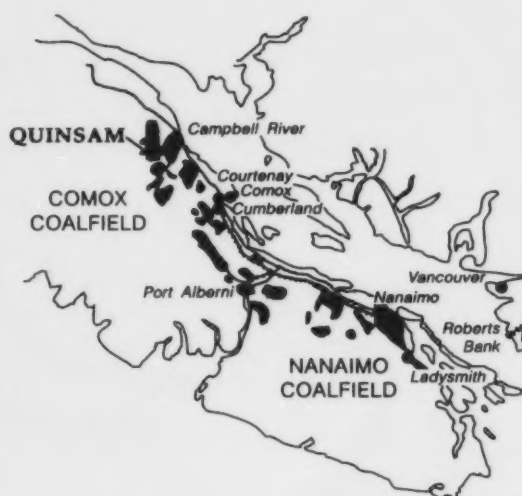
Figure 7.3

VANCOUVER ISLAND
COMOX NANAIMO COALFIELDS



LEGEND

- Existing Roads
- Existing Railways
- Existing Communities
- Existing Mines



Source: Ministry of Energy, Mines & Petroleum Resources

The only coal mine presently operating on Vancouver Island (Figure 7.3) is the Quinsam Mine operated by the Brinco Coal Corporation.

The Quinsam Mine, located 18 km from Campbell River, produces thermal coal for both the domestic and offshore markets.

Brinco Coal Corporation has been developing this modest operation on a measured basis. Production in 1989 was 197 000 tonnes with an anticipated increase to 600 000 tonnes in 1991. Coal recovery commenced from the surface, but in 1990 was supplemented with production from the newly developed underground mine. Production will continue from the surface at about 250 000 tonnes per year with underground rates climbing to 360 000 tonnes.

The product is transported by barge to nearby Texada Island where it is transferred to ocean going coal carriers.

Coal production and sales have steadily increased since 1970 to record levels in 1990. There is little doubt that coal mining in British Columbia has become a major component of the province's resource based economy. (Table 7.2)

TABLE 7.2

British Columbia Coal Production 1976 - 1990

Year	Tonnes
1976	7 537 695
1977	8 424 181
1978	9 463 920
1979	10 570 370
1980	10 823 530
1981	11 752 621
1982	10 645 842
1983	11 480 298
1984	20 739 725
1985	22 612 810
1986	20 851 972
1987	22 586 852
1988	24 813 082
1989	25 134 198
1990	25 809 000 (estimated)

Source: Energy Mines & Petroleum Resources

8. MARKETS FOR BRITISH COLUMBIA COAL

The use of coal in today's society falls into two broad categories; firstly that used for generating heat to raise steam for electric power generation, generally referred to as "thermal coal" and secondly, through the carbonization of coal to produce coke used in the iron and steel industry, called "coking coal". (The terms coking coal and metallurgical coal are synonymous.)

This terminology is carried forward into the market place and thus when discussing coal markets, we refer to the coking coal or thermal coal market.

British Columbia is somewhat of an enigma in that it is the second largest producer of coal in Canada, but it virtually does not consume any itself. For instance, of the 25.0 million tonnes of coal produced in 1990, 23.2 million tonnes or 95.5 percent was consumed outside Canada.

The bulk of the remainder was utilized elsewhere in Canada, mostly in power plants in Ontario with only minor quantities being consumed in the province.

British Columbia is also Canada's largest exporter of coal. It exports 78.4 percent of Canada's metallurgical coal and 50 percent of the thermal coal.

The province's principal markets for metallurgical coal are Japan, South Korea, Taiwan, Brazil and the U. S. A., plus fifteen other countries around the world. Thermal coal is destined for Japan, South Korea, Denmark and six other countries.

The Ontario Market

Ontario consumed 16 million tonnes of coal in 1990, accounting for 32 per cent of Canada's total consumption.

All coal used in Ontario comes from outside the province: in 1990 about three tonnes from the United States for every tonne from western Canada. Ontario Hydro began using

TABLE 8.1

DISPOSITION OF CANADIAN COAL 1990 Preliminary

	Production	Exports (tonnes)
Nova Scotia		
Metallurgical	513 505	384 671
Thermal	2 902 003	562 913
New Brunswick		
Thermal	547 632	
Saskatchewan		
Thermal	9 406 963	8 620
Alberta		
Metallurgical	5 434 446	5 421 860
Thermal	24 870 835	1 319 485
British Columbia		
Metallurgical	22 025 262	21 053 376
Thermal	3 154 897	2 058 293
Canada		
Metallurgical	27 973 213	26 859 407
Thermal	40 882 330	4 149 311
	68 855 543	31 008 716

Source: Energy Mines & Resources, Canada
(Statscan)

increased volumes of western Canadian coal in the 1980s for two reasons: to diversify its supply source and to obtain a low-sulphur grade of coal which can be blended with higher-sulphur American coal for lower gas emissions. Coal generates about 25 per cent of Ontario's electricity. Almost

all the coal consumed in the province is used either to generate electricity (60 per cent in 1990) or to make steel (31 per cent). Other uses including cement making accounted for 6 per cent of Ontario coal use.

As a source of energy for Ontario, coal is in reasonably secure supply. Western Canadian coal is generally lower in sulphur than the mid west and eastern U.S. coal, but not price competitive with U.S. coal delivered to Ontario. U.S. coals from the Powder River basin in Wyoming also have a price advantage over western Canadian coal.

An intergovernmental committee was formed in 1988 to investigate ways of reducing the cost of producing and delivering western Canadian coal to the Ontario market. The Committee identified a number of research projects in the areas of mine productivity, coal product improvement, transportation and regulatory changes. To date none of these has resulted in a significant cost reduction.

The low-sulphur western Canadian coal could have an advantage in the area of coal combustion, that being the issue of emissions. Ontario

Hydro has lowered the average sulphur content of its coal burn from 2.4 per cent to 1.2 per cent. The utility is under an environmental control order to reduce its total acid gas by about half from 1987 to 1994. Technologies which would make coal combustion cleaner are being developed. In Ontario the key short-term technology is flue gas desulphurization (scrubbers). For the longer term, attention is being directed at Integrated Gasification combined Cycle (IGCC) technology and fluidized bed combustion. These technologies are described in Chapter 12 and Appendix (B) of this report.

Only one mine in British Columbia supplies coal to Ontario Hydro, that being Byron Creek Collieries in the southeast corner of the Province. This contract expires in 1992 and there is concern about Byron Creek being able to compete with U.S. sources of low sulphur coal. The continued use of British Columbia coal by Ontario Hydro will depend largely on Ontario being desirous of maintaining security of supply.

All of the coal consumed by Ontario steel mills in 1990 was imported from the U.S.

9. CANADA'S ROLE IN THE WORLD COAL TRADE

In order to understand Canada's position in coal compared to the world as a whole, it is first necessary to look at the world's coal reserves followed by an examination of the annual production and consumption of coal. The British Petroleum Company p.l.c. publishes the BP Statistical Review of World Energy from which the following tables are sourced.

Canada has extensive reserves of coal available for development; indeed it is the country's single largest hydrocarbon resource (Figure 9.1). When compared to the rest of the world. Canada ranks twelfth in terms of coal reserves. There are over 30 countries producing coal. What should be noted, however, by referring to Table 9.1, is that three countries, the U.S.A., China and the U.S.S.R. possess 62 percent of the world's coal.

TABLE 9.1

1989 WORLD COAL RESERVES

	(billions of tonnes) (percent)	
U.S.A.	261.3	24.1
Canada	6.8	0.6
North America	268.1	24.7
Latin America	18.6	1.7
Western Europe	78.8	7.3
U.S.S.R.	239.6	22.1
Eastern Europe	89.8	8.3
Africa & Middle East	62.7	5.8
Asia	68.0	6.3
China	167.1	15.4
Australia	90.6	8.4
New Zealand	0.1	0.01
TOTAL WORLD	1 083.4	100.00

Source: BP Statistical Review of World Energy.

TABLE 9.2

1989 WORLD COAL PRODUCTION (Million Tonnes of Hard Coal Equivalent)*

U.S.A.	798.5
Canada	59.4
North America	857.9
Latin America	37.1
Western Europe	289.2
U.S.S.R. & Eastern Europe	858.3
Middle East	1.4
Africa	152.6
Asia	224.7
Japan	10.1
China	765.6
Australia	148.7
New Zealand	2.6
	3 348.2

* See Glossary of Terms, Appendix D

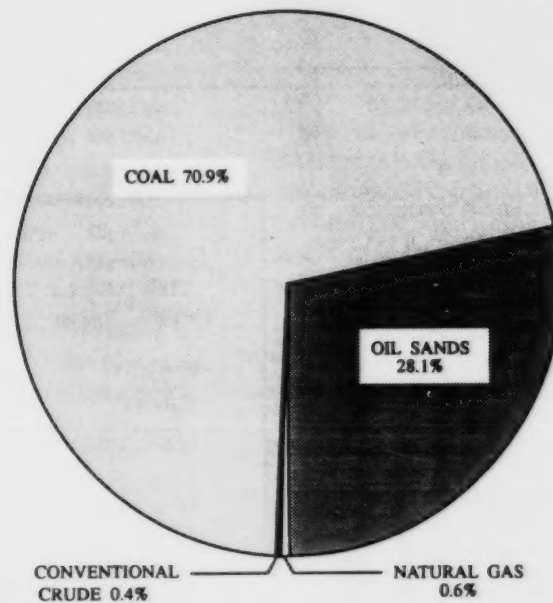
Source: BP Statistical Review of World Energy

These same three countries produce 61 percent of coal mined in the world (Table 9.2) and consume 57 percent of the total (Table 9.3). There are in excess of 33 countries that are large consumers of coal, many of which cannot meet demand from their indigenous sources. It is for this reason the inter-continental or seaborne trading in coal has evolved into such a large business. Table 9.4 shows world coal production in millions of tonnes.

It is in this seaborne coal trade that Canada plays an important role with approximately one half of the country's total production dedicated to this segment of the market. The major world coal exporters in 1990 were Australia, U.S.A., South Africa and Canada. (Figure 9.2)

Figure 9.1

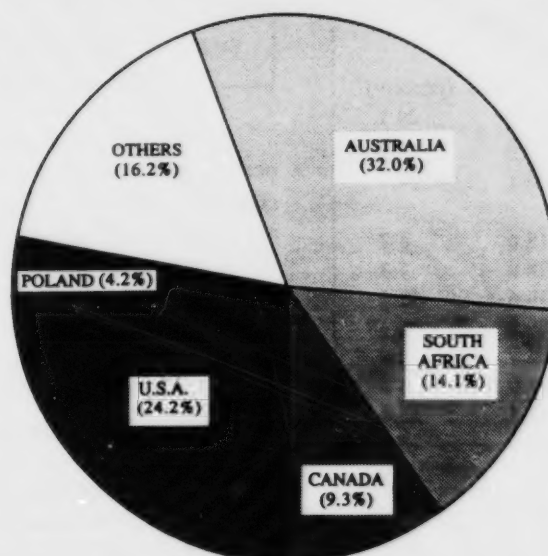
CANADIAN HYDROCARBON RESOURCES 1990



Source: Coal Association of Canada

Figure 9.2

MAJOR WORLD COAL EXPORTERS 1990



Total 330 million tonnes

Source: International Bulk Journal 1991

TABLE 9.3

1989 WORLD COAL CONSUMPTION
(Millions of Tonnes of Hard Coal Equivalent)*

U.S.A.	710.7
Canada	50.0
North America	760.7
Latin America	33.9
Western Europe	387.6
U.S.S.R.	432.9
Eastern Europe	389.3
Cyprus/Gibraltar/Malta	0.2
Middle East	3.9
Africa	113.3
Asia	292.8
China	757.4
Japan	113.1
Australia	60.2
New Zealand	2.6
TOTAL WORLD	3 347.9

* See Glossary of Terms, Appendix A

Source BP Statistical Review of World Energy

Of particular significance is the fact that metallurgical coal represents about 50 percent of the seaborne trade at 164 million tonnes and of this, some 70 million tonnes are destined for Japan.

Seaborne coal trade is of particular importance to British Columbia because 95.5 percent of the total production is exported. In some respects this is not a desirable position to be in because it leaves the Province vulnerable to the vagaries of the international coal market place.

World-wide coal trade reached a high in 1990 achieving a total volume of 330 million tonnes. This is a phenomenal increase of 74 percent over the past decade. Aggregate tonnage has risen from 189.6 million tonnes in 1980 achieving an average growth over the 10 year period of 5.7 percent compounded. (Table 9.5)

Although total volumes of coal have risen, world trade in metallurgical coal was down by two million tonnes last year. In the late 1970s many analysts were predicting world trade in metallurgical coal to more than double by the year 1990

Table 9.4
1989 World Coal Production
(millions of tonnes)

	Lignite ⁽¹⁾	Hard Coal ⁽²⁾	Total
Australia	46.9	147.8	194.7
Canada	31.7	38.7	70.4
Germany	109.9	77.5	187.4
Greece	55.0		55.0
Spain	21.9		21.9
United Kingdom		101.0	101.0
United States	79.5	804.8	884.3
Other OECD	55.0	46.2	101.5
Africa		188.6	188.6
China		980.0	980.0
India	9.0	194.0	203.6
North Korea	14.0	39.5	53.5
South Korea		22.0	22.0
Other Asia	14.0	16.5	30.5
U.S.S.R.	160.0	518.0	678.0
Bulgaria	33.0		33.0
Czechoslovakia	95.0	25.3	120.3
East Germany	290.0		290.0
Hungary	17.0		17.0
Poland	70.0	177.0	247.0
Romania	45.0	9.1	54.1
Other East Europe	70.0	2.5	72.5
Brazil		8.4	8.4
Colombia		18.9	18.9
Mexico		5.7	5.7
Other S. & C. America		4.0	4.0
	1 216.9	3 425.8	4 642.7

(1) Includes brown coal.

(2) Includes anthracite and bituminous coal and, for United States, Australia, and New Zealand, sub-bituminous coal

Source: IEA Coal Information 1990

resulting in a rush to develop new mines. The doubling in seaborne metallurgical coal trade has not materialized; however, the industry has managed to achieve an average growth of 3.6 percent compounded from 1980 to 1990.

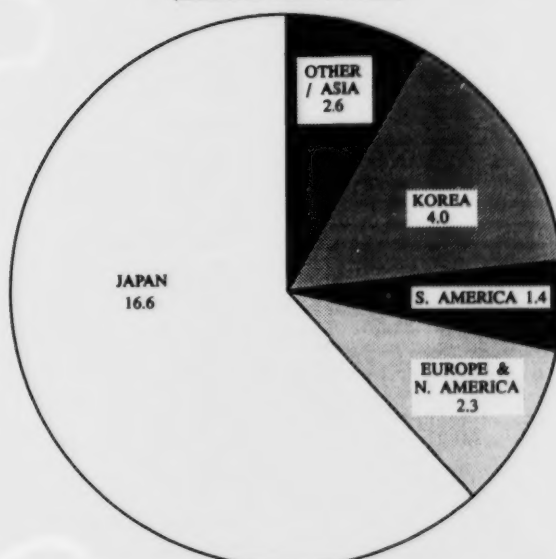
The thermal coal trade has demonstrated the most significant growth starting with 73.6 million tonnes per year in 1980 increasing to 166 million tonnes in 1990, averaging some 8.5 percent compounded per year.

Figure 9.3

CANADIAN COAL INDUSTRY

COKING COAL EXPORTS 1990

(millions of tonnes forecasted)



1990 Total = 26.9 million tonnes

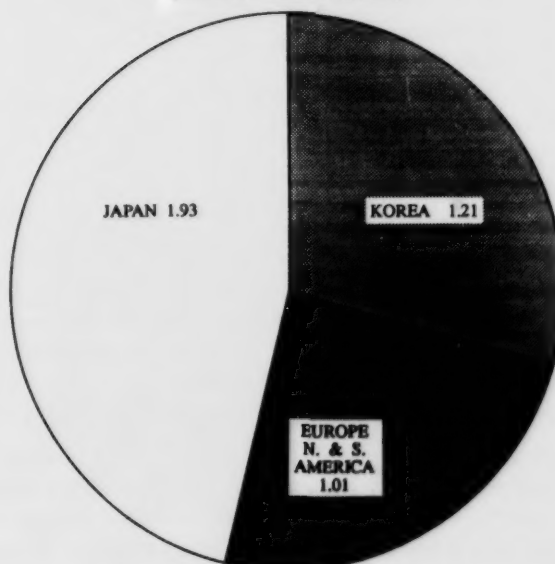
Data Source EMR/STATSCAN

Figure 9.4

CANADIAN COAL INDUSTRY

THERMAL COAL EXPORTS 1990

(millions of tonnes forecasted)



1990 Total = 4.15 million tonnes

Data Source EMR/STATSCAN

TABLE 9.5

SEABORNE COAL TRADE 1980-1990

Year	Thermal Coal	Metallurgical Coal	Total
	(millions of tonnes)		
1980	73.6	116.0	189.6
1981	84.4	120.7	205.1
1982	88.0	118.2	206.2
1983	86.2	111.0	197.2
1984	104.5	130.5	235.0
1985	131.6	143.9	275.5
1986	133.9	141.2	275.1
1987	137.9	145.2	283.1
1988	140.5	162.4	302.9
1989	151.0	166.0	317.0
1990 (est.)	166	164	330.0

Source: International Bulk Journal

TABLE 9.6

EXPORTS OF CANADIAN COAL BY TYPE
AND DESTINATION 1990

Country	Metallurgical	Thermal	Total
	(thousands of tonnes)		
Japan	16 569	1 933	18 502
South Korea	3 948	1 205	5 153
Brazil	1 108	98	1 206
United States	973	204	1 177
Taiwan	1 059	-	1 059
United Kingdom	645	19	664
Portugal	519	-	519
Denmark	-	479	479
France	379	18	397
Netherlands	369	-	369
Chile	223	129	352
China	300	-	300
Pakistan	208	-	208
Italy	159	-	159
West Germany	72	64	136
Iran	129	-	129
Sweden	102	-	102
Turkey	51	-	51
Finland	41	-	41
Belgium	6	-	6
Total	26 860	4 149	31 009

Source: EMR/Statscan

1990 was a significant year in seaborne coal trade in that the total tonnage of thermal coal movement exceeded metallurgical coal for the first time.

Canada's exports doubled from 15 million tonnes in 1980 to 31 million in 1990. Metallurgical coal continues to play the dominant role in exports at 86.6 percent of all exports. (Table 9.6)

New technologies incorporated into the steel making process which allow the use of lower quality, weak, or semi-soft coking coals have had a negative effect on the demand for high quality coking coal. The use of pulverized coal injection (PCI) has increased dramatically world-wide from three PCI units in 1980 to at least 73 such units by 1992, with 22 of the PCI units in operation in Japan. The market share of these lower quality coals has increased to about 20 percent of coking coal demand in Japan over the past decade.

While it is important to recognize that this technological innovation has improved the economics of steel making, it has had the opposite effect on the Canadian coal industry. Canadian producers' profit margin decreased due to the increased use of the lower priced weaker coking coals.

Pulverized coal injection is expected to increase world-wide from 28 kgs per tonne of steel produced today to about 58 kgs per tonne about the mid 1990s. This results in an overall reduction in demand for hard coking coal.

Japan continues to be Canada's largest market for both metallurgical (Figure 9.3) and thermal coal (Figure 9.4), although total volumes dropped by 1.2 million tonnes in 1990 compared to 1989. This is the first time the total volume of coal exported from Canada to Japan has decreased since 1986. Likewise, it is the first time since 1986 that Canada's total exports in coal have fallen off compared to previous years.

British Columbia's other major international customers include Korea, Brazil, U.S.A., Taiwan and United Kingdom.

10 CURRENT ECONOMIC CONDITIONS IN THE BRITISH COLUMBIA COAL INDUSTRY

The 1980s have been, to say the least, stimulating times for the coal industry, with the decade starting off in a state of euphoria. Demand for coal was on the increase and predicted to double before 1990. There was not sufficient production capacity in place to meet this forecasted demand and prices were on the rise. Coal producing countries serving the Pacific Rim market, particularly, were rushing to develop new mines to provide coking coal for the burgeoning Japanese steel industry.

Ten years later there are ominous dark clouds on the horizon and many coal producers are facing an uncertain future. During 1988 a number of underground mines in New South Wales, Australia, found that they were no longer economic and closed down. That year also saw a number of marginal producers in the Appalachian region of the United States close.

British Columbia coal producers have not escaped these events. Although it is the exception to the rule as far as closing mines is concerned, at least to date, the provincial coal producers have had to face and overcome many challenges. The difficulties, however, have not ended. Within the last six months, two coal mines in the province have been listed for sale by their owners. Others are struggling to make ends meet. Over the last nine years of operations, the industry has consistently shown a financial performance that failed to achieve rates of return on capital employed greater than 2.5 percent. In 1990 the coal industry showed a net loss of \$24.0* million in spite of record sales. For 1991 early indications are that the financial performance will be even worse.

Concern is being raised these days about the economic viability of the export coal industry and there is a further concern about loss of market share. These indeed are serious issues that must be addressed.

The coal industry is an important component of British Columbia's economy. It generates more gross revenue than any other single mineral commodity in the province. (Figure 10.1) Total gross revenues last year were \$1.6 billion which does not include income from transporting coal from other provinces to British Columbia ports and into the ships.

Coal is also a significant source of tax revenue for local, provincial and federal governments. The industry's total tax payments, including all indirect taxes amounted to \$96 million for 1989. An additional \$75 million in income taxes was paid by the industry's employees.

The industry makes every effort to support British Columbia and Canada based firms and industries. Of \$374 million in direct materials, equipment and contract work expenditures, Canadian and provincial suppliers accounted for 93 and 80 percent respectively. In addition to the industry's 5,600 direct employees, approximately 16,000 individuals depend on coal mining for their living.

Indeed, the economic well-being of both the southeast and northeast regions of the province is closely linked to coal mining. Therefore, any situation having a negative impact on the industry is of particular concern to these communities.

The communities supporting the coal industry are normally the first and hardest hit with any downturn in the trade, but the impacts go further. The tax base is eroded, employment declines, the service sector suffers and there are other major impacts that are not so obvious. For example, 60 percent of the volume of Canada's

* After extraordinary items and adjustments. The Coal Association of Canada, Review of the British Columbia Coal Industry for 1990.

two national railways is west of Ontario. Coal is the largest single bulk commodity carried by these railways and the coal industry pays its full share of the costs. A loss of this large component of the railway traffic would have a devastating consequence for the remaining shippers on these railways. This same situation also applies to the British Columbia Railway. It is often said that the coal sector carries more than its share of the burden for Canadian railway transportation.

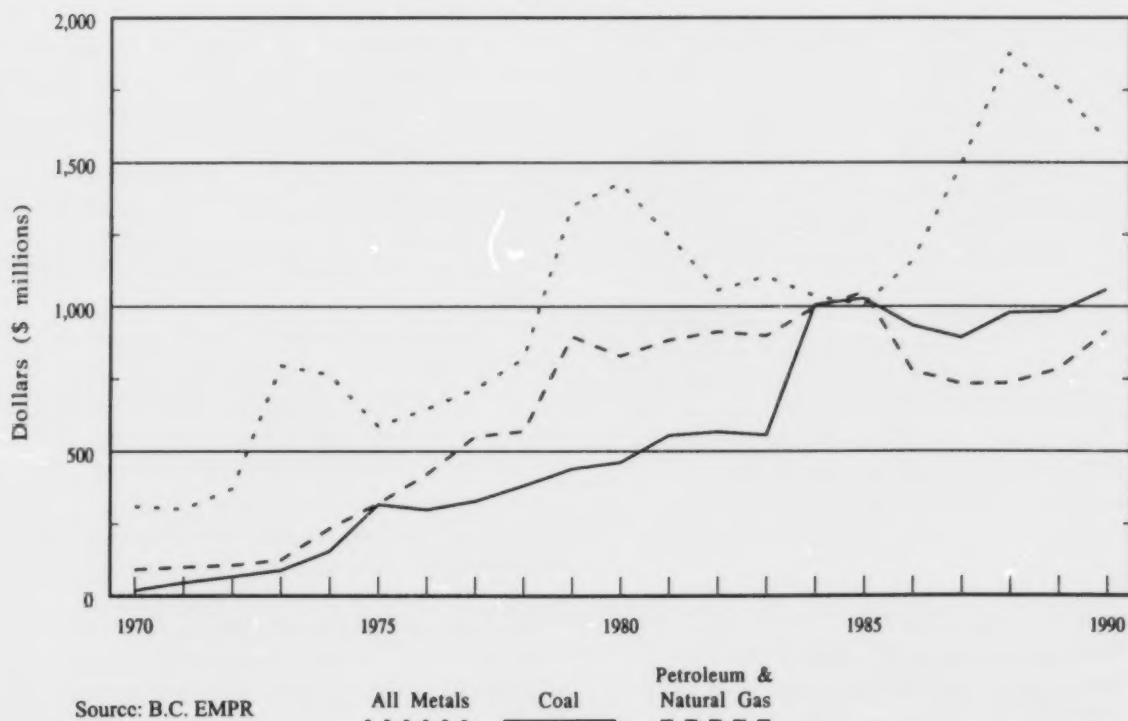
When a major industry faces economic uncertainty, the fingers start pointing in all directions to find the culprit, to locate a scapegoat upon which to place all of the blame. In reality there is seldom any one entity or single situation causing the problem, but a multitude of decisions, actions or events. Finger pointing accomplishes nothing in reaching a solution. What is required is an objective analysis of the situation, including some self assessment and then to develop an appropriate action plan.

To understand the concern over the industry's economic viability, it will be worthwhile to examine some of the events leading up to the current situation.

During the post second world war years, demand for steel in Japan was growing in leaps and bounds. To satisfy this requirement, the Japanese constructed the most modern steel mills in the world. In order to raise foreign currency Japan started exporting quality steel and was soon one of the largest and most modern steel suppliers in the world.

To meet the requirements of raw material supply for their steel industry, Japan commenced seeking reliable sources of iron ore and coal. During the 1960s and early 1970s, Canada and Australia responded to this market situation. Both of these countries had large reserves of good quality metallurgical coal with only modest domestic requirements. Coal shipments commenced from existing mines, but the largest

Figure 10.1
PROVINCE of BRITISH COLUMBIA
MINE SITE VALUE of MINERAL PRODUCTION
1970 - 1990



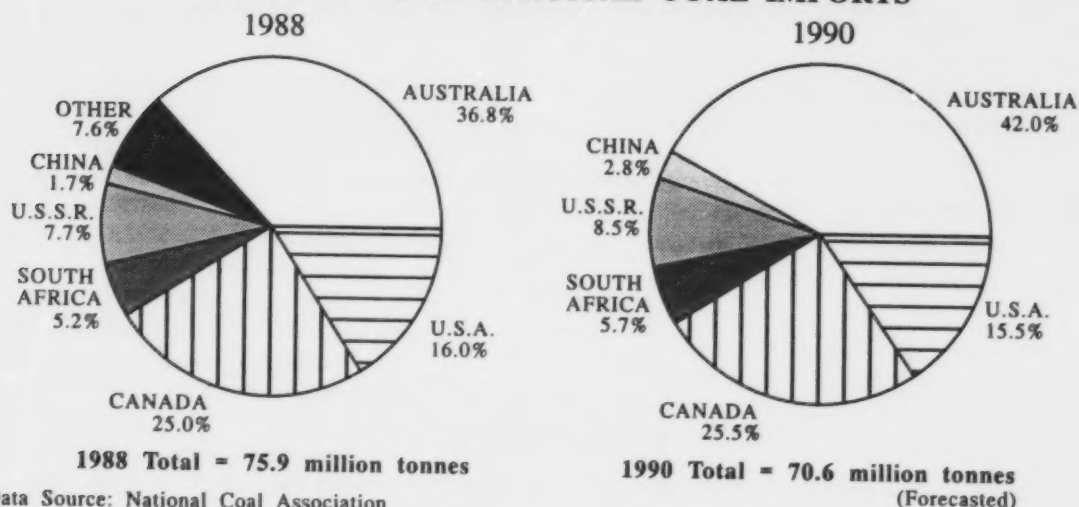
volumes originated from new mines. Considerable capital was invested in each country by both industry and governments to develop these new mines and the associated infrastructure.

Japan very quickly became the world's largest importer of coal and Canada along with Australia were its largest suppliers. (Figure 10.2) Demand for steel continued to grow and supply of coal was barely able to keep up with demand. Therefore in the 1970s Japan, based on its forecasted demand, once again embarked on an aggressive coal purchasing program. For a number of reasons, one being security of supply, and a second

These latter mines were developed at a time of high financing rates which resulted in higher operating costs and necessitated higher selling prices. The Japanese in their desire to secure long term coal supplies agreed to pay these higher prices for this new production. The result, however, was a two price system for Canada, one for the new suppliers and another for what has been termed the traditional suppliers. It is an important consideration that this factor be recognized for this is the reason British Columbia is at the high end of the Japanese supply portfolio. (Figure 10.3)

Figure 10.2

JAPANESE METALLURGICAL COAL IMPORTS



the objective of trying to maintain favourable pricing arrangements, the Japanese contracted more coal than they required. Having limited indigenous resources, they were becoming increasingly dependent on external sources.

British Columbia again responded to this growing market for coal and during the early 1980s, the industry invested over \$2.0 billion of additional capital in the expansion of existing mines, and the development of five new mines, increasing annual production capacity by 14.9 million tonnes. At the same time the provincial and federal governments invested over \$1.5 billion to provide infrastructure for this new production capacity.

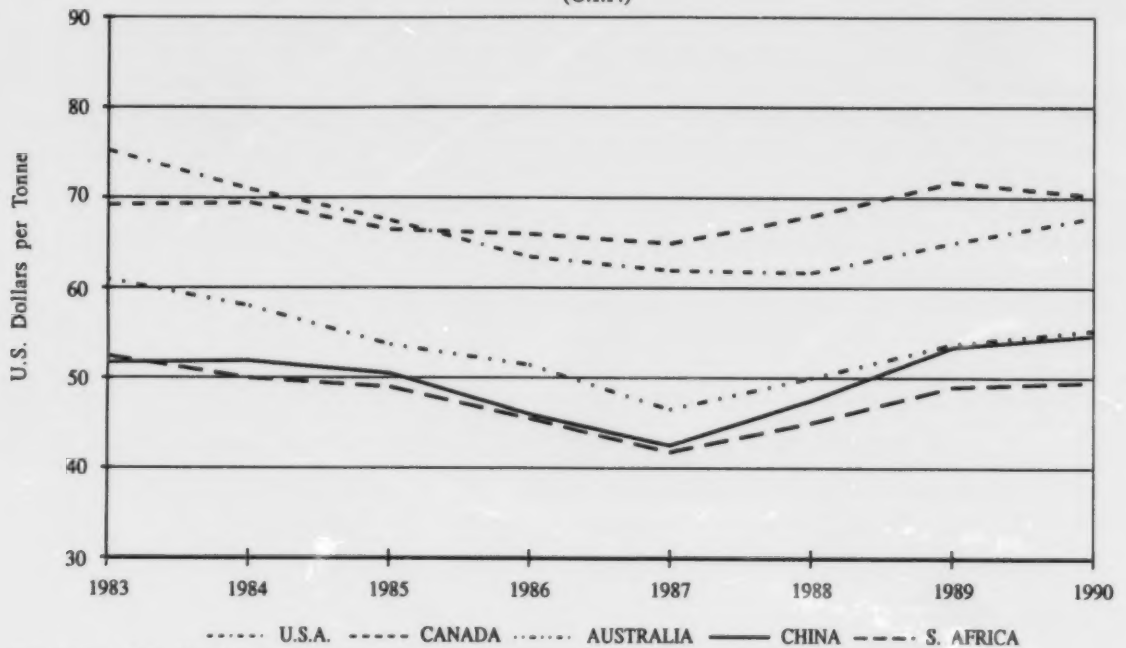
Korea and Taiwan were also building new steel mills in the late 1970s and early 1980s and they too were acquiring long term supplies of coal. The Japanese, however, because of their dominant position, became the price setters in the seaborne coal trade.

As a result of the oil crisis of the 1970s, the demand for thermal coal traded internationally was on the increase and Japan also became a major consumer of imported thermal coals, once again dominating the Pacific Rim scene.

In the thermal coal trade, Australia became the predominant supplier capturing 61 percent of Japan's requirement. Canada only supplies 5.6

Figure 10.3

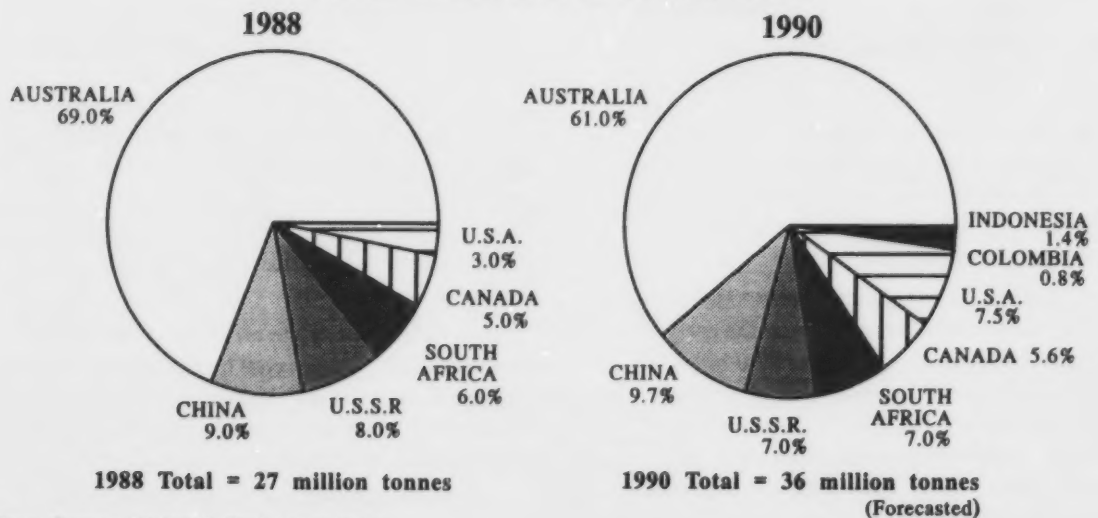
JAPANESE PRICES OF IMPORTED METALLURGICAL COAL (C.I.F.)



Data Source : Mitsubishi Canada Limited

Figure 10.4

JAPANESE THERMAL COAL IMPORTS



Data Source: National Coal Association

percent of Japan's needs in thermal coal. (Figure 10.4)

With this growing demand for coal world wide, accompanied by increasing prices, why are the world's coal exporting countries, particularly the British Columbia producers in such a precarious economic situation at this time?

There are a number of factors that contributed to the problems of today. Firstly was the world wide recession of 1982. As a direct consequence, the demand for steel did not reach the levels anticipated. Indeed, even now it has not reached the levels some analysts were predicting. Demand for coal in the consuming countries could not keep pace with the installed production capacity. This situation was further aggravated by the fact, as mentioned previously, that Japan was purposely over-contracting supply requirements. A huge oversupply of coal was the net result.

The steel mills of the world suffered from a drop in demand resulting in lower prices for steel. The Japanese mills did not escape this situation and looked to coal suppliers to share some of the burden in reducing production costs of steel. The coal producers had made substantial investments in mine development and had long term supply contracts. Therefore it was in their interest to keep the new mines operating. The Japanese steel mills, through their astute purchasing practices and dominant, oligopsonistic, purchasing power, having thoroughly evaluated each producer's costs, were able to set prices marginally above those costs. It was for this reason that some of the older, more expensive producers in Australia and the United States ceased operations.

The British Columbia coal producers were fully exposed to the impacts of this situation. The fact that over 95 percent of the coal produced is exported leaves the industry in the province particularly vulnerable to the vagaries of the coal market place. In this market, product supply and demand, and ultimately prices, are shaped by global economic forces, which are largely beyond the control of any one supplier.

Exacerbating the problem in Canada was the fact that many of the contracts were signed in U.S. dollars and the high interest rate policy of Canada's federal government, coupled with a strong Canadian dollar supported by this high

interest rate policy, eroded the industry's profitability.

The Bank of Canada has kept interest rates high for several years. This has a damaging effects on Canadian corporations, on the federal deficit and on the Canadian dollar, forcing it upwards to an untenable level.

The resulting high dollar has damaged the Canadian export sector. For the coal industry alone, since 1988, revenue losses due to this policy have topped the \$220 million mark. The longer we damage the economy by a high interest-dollar policy, the lower the dollar will be when the correction eventually occurs. Comparative exchange rates with competing coal suppliers are shown on Figure 10.5.

An argument can be made for the sales agreements to be priced in Canadian dollars and, indeed, there are a number of Canadian producers who transact their business in Canadian funds. The fact remains, however, that a high percentage of the export contracts are priced in U.S. dollars with full exposure to the exchange rate fluctuations. For example, a five cent (U.S.) change in the Canadian dollar value equates to a (U.S.) \$3.00 per tonne impact on prices received by a Canadian mine.

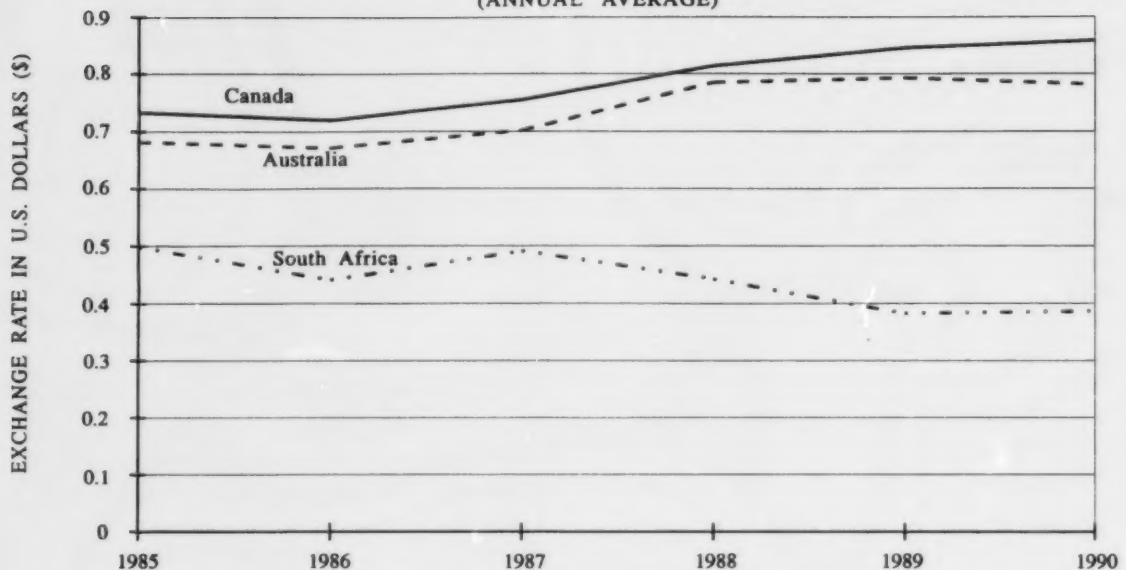
From 1982 to 1988 applying the appropriate exchange rates results in a price decrease of 33 percent; when adjusted for inflation this equates to a 49 percent decrease. In yen terms adjusted annually, the coal price over the same period fell some 63 percent (Figure 10.6).

It is also worthy of note that the cost of Canadian coal in Japan fell at much higher rates than the corresponding price for steel (Figure 10.7). The impact of inflation to the Canadian producers is graphically demonstrated in Figure 10.8.

Therefore the producers are faced with declining prices in real terms for their product while the consumers end up paying less for the coal. At the same time steel prices have not fallen to the same extent and steel manufacturers, particularly in Japan have been rewarded with high profit levels.

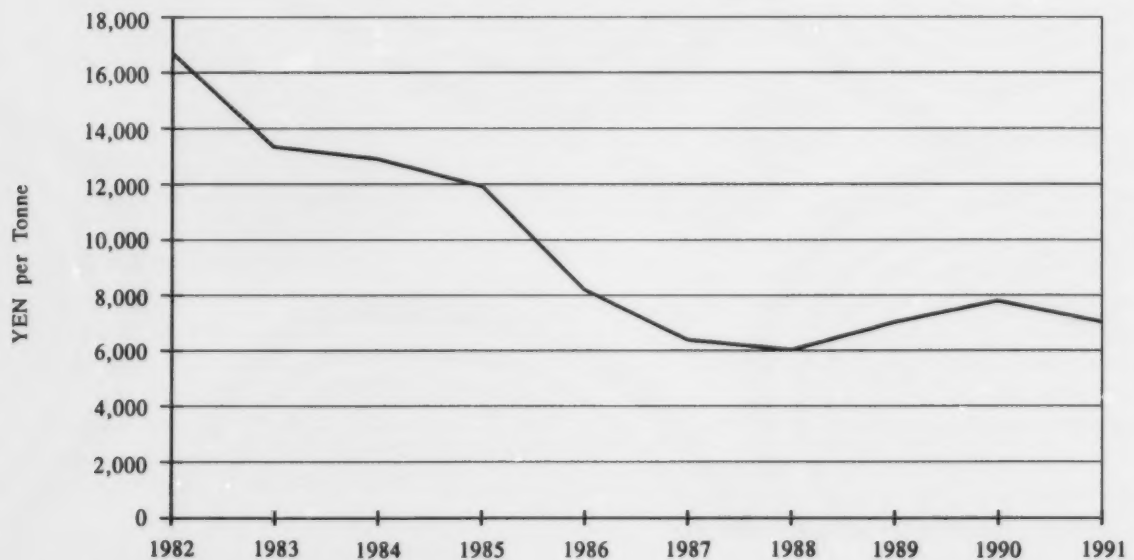
In addition to the impact of exchange rates and inflation, other costs were increasing, property

Figure 10.5
COMPARATIVE EXCHANGE RATES
(ANNUAL AVERAGE)



Data Source : I.M.F.

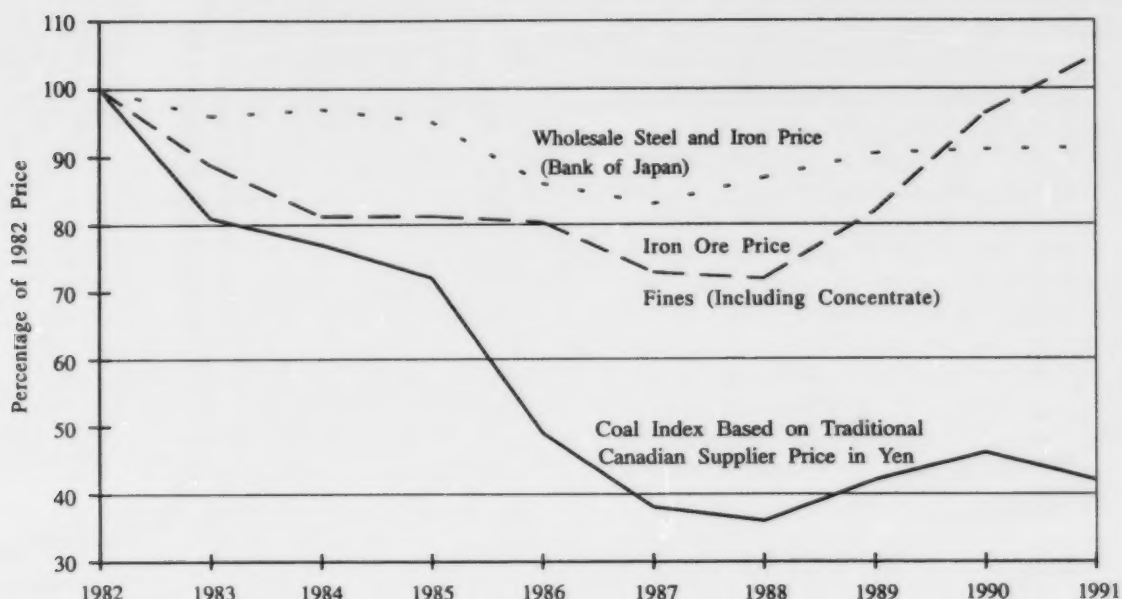
Figure 10.6
JAPANESE METALLURGICAL COAL PRICE IN YEN EQUIVALENT *
(Adjusted annually)



TRADITIONAL CANADIAN SUPPLIERS

* Based on exchange figures supplied by Royal Bank of Canada

Figure 10.7
COAL/IRON ORE/STEEL PRICE COMPARISON *



* Based on exchange figures supplied by Royal Bank of Canada

taxes were rising, there were demands for increased wages, rail and terminal costs were also at a higher rate leading to an overall rise in operating costs.

Industry responded by mitigating the effects of the negative impact on the prevailing economic conditions. First and foremost was the determination to increase productivity which resulted in decreased employment levels, increased equipment utilization and innovative mine planning.

The service sector assisted the effort by holding down cost increases for materials and supplies. Railways and ports also made an effort to help the producers.

Prices continued to deteriorate and producers were forced to postpone investing sustaining capital in order to remain financially viable, but sooner or later, such actions ultimately result in cost increases and threaten economic viability.

Despite the efforts by each coal producer to reduce costs, increase efficiency and expand markets, the industry continued to record disappointing financial results. The fact that industry

received a price increase in 1990 and still recorded an overall loss*, cannot go by unnoticed. With a \$1 per tonne reduction for metallurgical coal in 1991, there has to be serious concern about the ability of some producers to survive.

One must be careful about dealing with an industry as a whole because it is easy to create misconceptions. Each mine has its own individual circumstances from unique geological conditions, varied coal characteristics through to management philosophy and profitability.

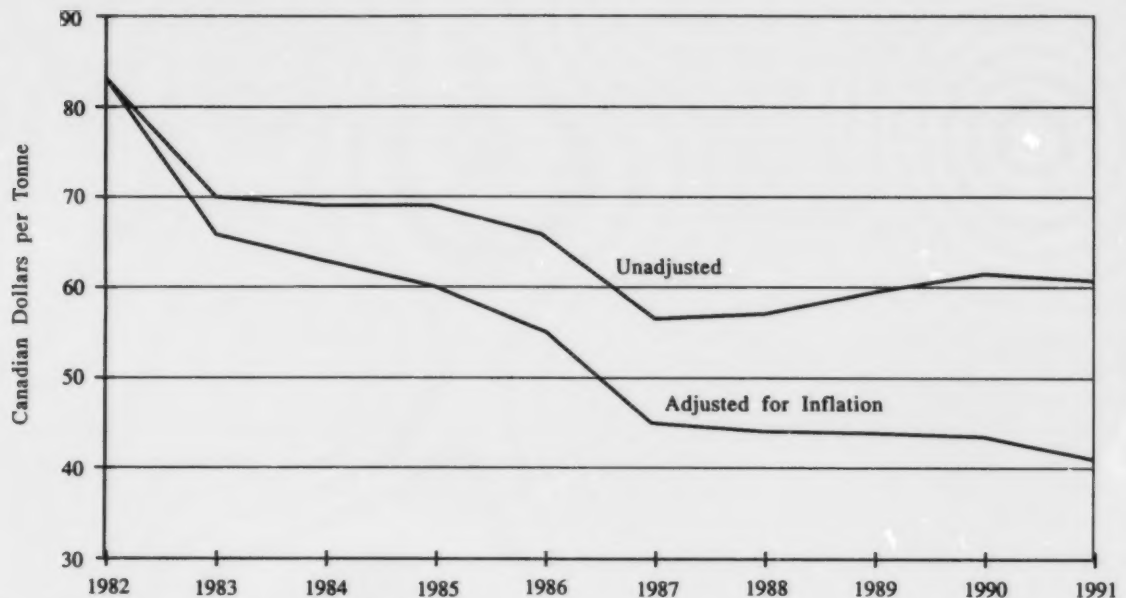
Therefore it is fair to say that in any given set of circumstances, some firms will fare better than others. The fact remains, however, that for the coal industry, the marketplace for whatever reason has not been kind. Even the best producers along with those that are marginal have suffered.

British Columbia is facing tougher challenges today than it did throughout the 1980s. The survival of some of the producers is in serious

* The Coal Association of Canada, 1990 Review of the British Columbia Coal Industry.

Figure 10.8

JAPANESE METALLURGICAL COAL PRICE IN CANADIAN DOLLARS



TRADITIONAL CANADIAN SUPPLIERS

doubt. If one or two mines should close this would cause a domino effect that could have negative impacts on remaining mine operations.

This being the case, then we have to look hard at our economic competitiveness. In any market this is measured against the lowest cost competitor.

Australia is Canada's competition in the Pacific Rim coal market and they are a very worthy competitor.

Australia has extensive reserves of coal, good mining conditions and they are close to tidewater. In recent years as a result of the Coal Industry Tribunal which examined work practices in the coal industry in 1988, an accord was reached between labour and management that resulted in a reported 15 percent increase in productivity leading to a possible additional 10 million tonnes available for export despite a number of mine closures.

In addition to this increased volume, three new mines are being developed in Australia, Gordonstone and Ensham in Queensland and Campbellwell in New South Wales.

Of interest is the fact that the proponents of these mines are prepared to invest on the basis

of a shorter term supply contract, five years, compared to the normal 15 year term common in the past. It should also be noted that capital costs for construction of new mines is less in Australia than in Canada.

There was a general consensus in the industry that a balance of supply and demand would occur in metallurgical coal trade this year. However, with this incremental supply and new production from Australia, any possible balance between supply and demand will be some time into the future.

All of the Canadian producers indicated that they were fully competitive at the mine site, the variable being the cost of inland transportation and terminal charges. It cannot be denied that we do face longer inland transportation distances than competing countries (Table 10.1) and this impacts on our cost structure. Canadian coal is sold loaded on the ship at the port. Thus inland transportation and port handling charges are to the account of the producer. Any increased cost of this service erodes profitability and ultimately competitiveness.

Obviously some provincial producers remain fully competitive at the port, but even they

TABLE 10.1

TRANSPORTATION DISTANCES ON
SELECTED RAIL ROUTES

Canada	Miles	Kilometers
N.E.B.C. to Price Rupert	750	1 207
S.E.B.C. to Roberts Bank	700	1 127
Australia		
Hunter Valley - Newcastle	100	161
Picton - Port Kembla	50	80
Bowen Basin - Hay Point	94	150
Bowen Basin - Gladstone	124	200
South Africa		
Transvaal - Richards Bay	350	503
Transvaal - Maputo	300	483

Source: IEA Coal Research EAS Report No. G3/82

are feeling the impacts of increased costs and reduced prices.

Another factor impacting the demand for metallurgical coal is the technique of injecting pulverized coal (PCI) into the blast furnace which reduces the amount of coke required with a consequent reduction in the amount of quality metallurgical coal required to make the coke. PCI coal also commands a lower price.

In some quarters it is felt that as PCI rates increase, a higher quality or stronger coke will be required thus providing an opportunity for increased use of British Columbia metallurgical coal. Coke rates per tonne of steel are expected to drop from 475 kgs to under 450 kgs in the next two to three years.

The amount of coal used for PCI will increase and it is expected that annual volumes in seaborne trade of PCI type coal will range from 10 million tonnes in 1990 to 14 million tonnes in 1992.

There does not appear to be consensus on the best type of coal for PCI use world wide, as quality and chemical requirements vary, but one

can rest assured that price will continue to be an important consideration.

The implication of PCI, of course, is that the shippers of hard coking coal, which include all the British Columbia large-scale operations, will see their sales volumes under pressure.

The private sector and the Province have invested substantial amounts in providing mines with productivity rates among the highest in the world and one of the finest transportation and port systems in the world. These facilities were installed on the basis of long term supply contracts justifying the large capital investments. The trend now appears to be to short term contracts. Producers are reluctant to re-invest capital when they are unable to see any return. These actions have left many British Columbia mines in a position where they are unable to recover their capital invested.

It is predicted that the lack of adequate returns has reached the point where a massive restructuring of the industry is about to occur. The first signs of this are already taking place. During 1989 Esso Resources Canada Limited placed their Byron Creek Collieries on the market. This action has not led to a completed sale and the mine is only maintaining the supply of coal to its principal customers and faces the possibility of closing when these contracts expire in 1992.

Crows Nest Resources Limited recently announced that they have sold the Line Creek Mine to Manalta Coal Ltd. of Calgary.

In March 1991 Teck Corporations made arrangements with Denison Mines Ltd. to take over operations of Quintette, currently operating under protection of the courts.

This malaise is not unique to Canada. It has recently been announced in Australia that CRA Ltd. are making an offer to take ownership of Coal and Allied Industries Ltd. and in the United States it is reported that Consolidated Coal are selling a fifty percent interest of their company to Rheinbraun Coal of West Germany.

The dilemma the coal producers of British Columbia finds themselves in could well lead to mine closures. The first stages of a survival strategy include the recent round of mergers and takeovers. It is interesting to note that within Canada there is only one oil company that contin-

ues to be directly involved in coal operations, and they are hoping to dispose of their mine.

This may appear to be a pessimistic appraisal, but it should not be viewed as the end of the world for the provincial coal industry because it is far from it. Yes, there are some companies that are experiencing serious financial difficulties, others who for one reason or another have decided to leave the industry, and there are those who have no other intention but to be a vibrant part of the

continuing coal business for Canada. There is no question, however, that if British Columbia is going to maintain a healthy coal industry, and the resultant benefits, all the issues identified are going to have to be addressed.

So far this study has focused on the problems facing the British Columbia coal industry. It should also be remembered that the industry has some strong points as well.

11. THE IMMEDIATE PROSPECTS

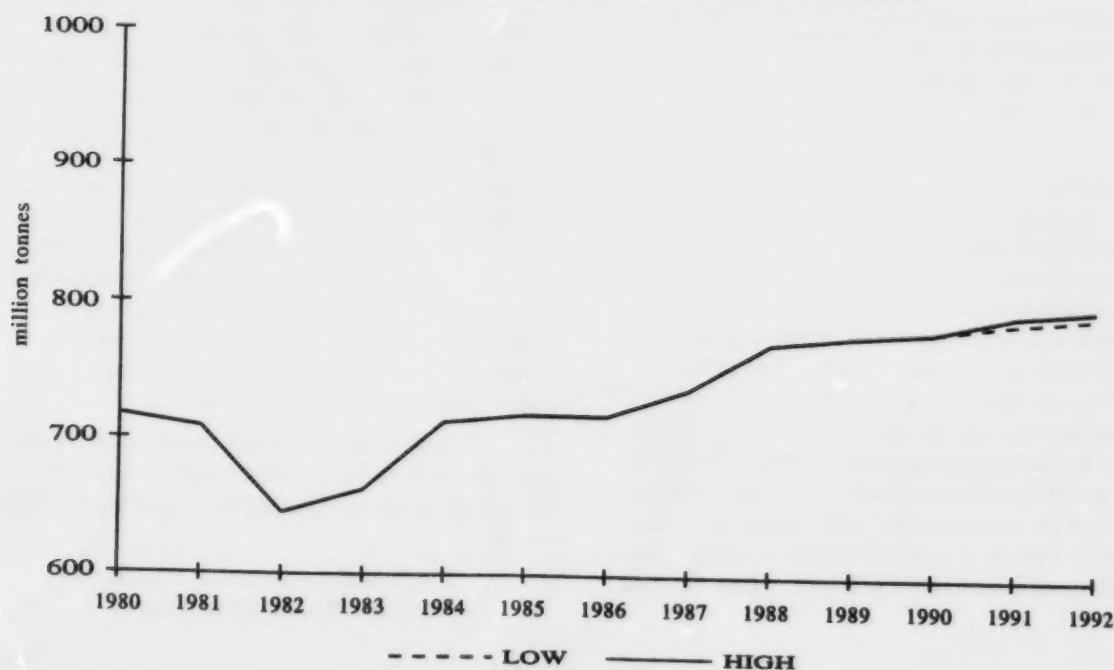
Current problems facing the coal industry have been identified leading to a degree of uncertainty about its future. Despite this air of uncertainty, there are many positive aspects that also have to be considered.

Probably the most important of these is that the world is not going to stop using coal. In fact, total world consumption is increasing. The pattern of coal trade is going to undergo structural changes and producers will have to adjust to these changes if they plan to stay in the business. Competition is going to increase and price adjustments will occur. Producers in the future are going to have to be increasingly aware of changing circumstances and build more flexibility into their operations.

The projected growth in steel demand is relatively flat with an annual increase forecast somewhere between 0.5 and 1.0 percent. World crude steel production continues around the 735 million metric tonne mark (Figure 11.1). Even with changing technologies, coal demand for the steel industry remains at relatively high levels. What will likely take place is a repositioning of steel production levels by various countries. In the next few years the European countries will continue to produce about the same levels, while Japan is expected to fall from the 108 million tonnes in 1990 to around 105 million. The developing economies should show fairly high levels of average growth in crude steel production, and thus the prediction for a levelized growth pattern.

Figure 11.1

WORLD CRUDE STEEL PRODUCTION



The amount of coal consumed for blast furnace coke is expected to fall off in the near future with the sharpest drop seen for Japan. There will be increases in the use of soft coking coals in blends for making coke. Thus reducing demand for hard coking coals.

The amount of coal used for PCI will increase and it is expected that annual volumes in seaborne trade of PCI type coal will range from 10 million tonnes in 1990 to 14 million tonnes in 1992.

Steel manufactured by the electric furnace method which does not require coke, is increasing and now accounts for about 27 percent of total steel production in Japan.

The implication of these factors, of course, is that the shippers of hard coking coal, which is all the British Columbia large-scale operations, will see their sales volumes under pressure. To some extent, this will be offset by increased requirements in the developing countries.

Although Canadian producers will face reduced volumes in Japan, other markets such as Korea should remain stable.

Canadian metallurgical coals possess some physical characteristics that can make them more attractive than the competition, such as low oven wall pressure in the coke ovens, that should allow the producers to exploit selective markets to replace volume reductions in Japan. Canadian coals are perfectly suited for application as PCI in some European steel mills, but price competition will be severe.

The demand for thermal coal continues to be strong in the short term, with some projections for the longer term indicating a doubling by the year 2000 (Chapter 13.2). The Pacific Rim forms an important part of this demand. Canada can be an attractive source of thermal coal for the export market and has the potential to play a greater role, particularly in the Asian market. This potential will not be taken full advantage of, however, because prices are not sufficient at this particular time to warrant any aggressive pursuit of markets for most Canadian producers. Therefore, developers will not invest in new mine development until there is a sense of more economic certainty. The coal resources are in the province - when the time

and conditions are right, they will be developed.

In the past the Canadian coal industry, including the producers, the work force, railways, terminals and suppliers have responded in times of adversity to make the industry as competitive as possible through:

- significantly reducing non-essential manpower levels while at the same time increasing efficiencies
- investing heavily to reduce transportation costs and minimize transport time from mine to port
- embracing the latest technologies in both mining and transportation
- going out of its way to maintain the reputation of the Canadian coal industry as a reliable supply source for coal
- consistently ensuring product quality and availability

The industry will continue to address the challenges facing it and will make adjustments as required to maintain its presence in the market. Canada wishes to maintain its role in the seaborne coal trade, but the hard economic reality cannot be ignored. If prices do not realistically reflect the cost of mining and moving the product, the time will come when this reliable source of supply may not be available in the manner it is today.

It is not visualized that any mines will close down in 1991, but it cannot be overlooked that there are some producers that are only marginally economic and further price reductions, or a higher Canadian dollar, could have precipitous results. For this reason, it is important for all participants in the industry, be it the mining companies, the railways, the terminals, the labour force, the communities, government or customers, to take a hard look at how each can best structure itself and take whatever actions are necessary to ensure the industry in the 1990s is healthier in order for it to continue providing the economic benefit all have enjoyed in the past.

Each of the provincial coal producers were interviewed and four concerns were consistently identified as being of paramount importance. These were:

1. The federal government's interest rate policy and the Canadian dollar.

2. Production subsidies and other direct government assistance provided to coal producers in the EEC and Japan.
3. Fuel taxes on rail transportation of coal in Canada.
4. High property taxes and the trend of high municipal spending in communities supported by the coal industry, which rank near the top of all Canadian communities.

Even though the serious state of the coal industry is acute, British Columbia will continue to participate in the international market.

It should be remembered that a more favourable exchange rate, realistic pricing and/or equitable taxation policies could turn the industry around fairly quickly and return it to a state of financial stability.

A satisfactory resolution of items 1 and 2 plus relief in 3 and 4 will go a long way towards achieving this financial stability.

12. TECHNOLOGICAL FACTORS LIKELY TO AFFECT COAL USAGE

In today's industrial society there are two forces that create change:

The first is the requirement to have a product that is price competitive. To accomplish this requires a source of raw material, a skilled labour force, a technologically advanced process and a market. To maintain market share requires keeping ahead of the competition. This involves tight control over production costs and utilizing latest technology or developing new technology. If an industry does not keep current and react to changing times it will not survive; thus change is necessary.

The second force that is creating change today is environmental concerns. The insistence of the general public that more attention must be paid to environmental protection is forcing industry to be more aware of the environmental impact of their actions. This awareness is causing industry to seek improved methods of processing, manufacturing and utilization of our natural resources. The industry is currently more than adequately meeting the required standards however public pressure on government has been forcing even higher standards. Therefore new technologies are being sought that will alleviate some of the environmental concerns. Again, a change over the status quo is required.

Practical responses to these pressures which are driving change, interestingly, encompasses technological advancement that in turn requires capital.

The metallurgical coal industry:

The steel producing countries of the world are continually seeking ways to reduce raw material costs, improve quality and reduce overall production cost. Japan is one of the more aggressive in this area and is on the leading edge of

technologies in steel making. Many of these technologies affect the way coal is or will be used in the steel making process in the future.

Chapter 12.1 is a description on the impact of changing coke making and iron making technology on coking (metallurgical) coal demand. This report has been prepared by H.N. Halvorson Consultants Ltd. Section 2 of the report "Executive Summary and Conclusions" is included in chapter 12.1. Dr. Halvorson's entire report is included in appendix "A".

The thermal coal industry:

In response to rising public concerns about the environment, new technologies are being developed to generate electricity from coal. These technologies, often referred to as clean coal technologies, are summarized in Chapter 12.2.

12.1 Impact of Changing Coke Making and Iron Making Technology on Coking Coal Demand.

The steel industry is actively exploring new steelmaking technology. This follows a period of approximately two decades of stagnation. Since the introduction in the 1960s and 1970s of basic oxygen steelmaking and scrap-based mini-steel mills (electric arc furnace), there has been little fundamental change in steelmaking technology. The underpinnings of the industry still remain the coke oven and the blast furnace. In the last few years a concerted effort has been launched to develop new technology that will divorce steelmaking not only from coke but also from the blast furnace. In addition the development of thin dimension continuous casting has opened up the whole flat product market to mini-steel mills using scrap iron.

The driving force behind the move to coke-free steelmaking is twofold: (1) to reduce

costs by substituting lower value coals for coking coals and (2) to alleviate the pollution problems inherent in cokemaking.

There seems little doubt that major changes are coming that will reduce and/or eventually eliminate the need for coking coals in steel-making. The only uncertainty is the timing of the changes and hence the rate of decline of coking coal consumption.

Superimposed on this trend to new technology is the fact that steel production is expected to stagnate or even decline in developed nations but grow rapidly in the developing world. Because of capital constraints and smaller market sizes, the developing world will desire smaller sized production units requiring flexible equipment and technology.

12.1.2 THIN SHAPE CASTING

The U.S. mini-steel company, Nucor Corporation, has successfully commercialized the continuous casting of a 25 mm thick steel plate that can be reduced on a cold mill to steel sheet. This has divorced sheet making from the intermediate step of hot rolling. Hot rolling mills are very expensive and require throughput rates in the 2-3 mtpy range. The inability of the mini-mills to justify hot rolling capacity has kept the large flat product market as the last preserve of the integrated steel companies.

Nucor Corp. has yet to prove its ability to produce high quality, cold rolled sheet. Success is fully expected by many in the industry. In addition, considerable effort is being spent worldwide on making near-net flat shapes (a few millimetres in thickness) that may make cold rolling unnecessary.

In the short term (to 1995), 3-5 mtpy of Nucor type capacity may be built in the U.S. Allowing for some BOF closures, this additional tonnage might increase total scrap based, electric furnace share of U.S. steel production to 45% from today's 39%. Some capacity is also expected in Italy and perhaps Spain. Also some electric furnace capacity will likely be built in the developing world.

After 1995, providing the production of quality sheet is perfected, considerable growth in electric furnace steel production is likely. This study forecasts that by 1995, 2000 and 2005, perhaps 37%, 50% and 52%, respectively, of total

western world steel will be made with electric furnace facilities. This translates into approximately 20, 70 and 80 mtpy in 1995, 2000 and 2005, respectively, less coking coal being required than if the 1989 electric furnace share of 32% had prevailed. The corresponding reductions for Japan are 1, 2 and 2 mtpy less coking coal in 1995, 2000 and 2005, respectively.

12.1.3 COKE MAKING TECHNOLOGY

The Japanese steel industry has commercialized a number of cokemaking changes that have reduced the amount of coking coal required per tonne of coke made. The main techniques include the use of briquetted non-coking coals in the coke oven charge, fine grinding and sizing of coal, predrying coal and dry quenching of the coke product.

The Germans have launched a major project to develop Jumbo reactors for use in cokemaking. A major benefit is the ability to make quality coke from non-coking coals.

This study forecasts that further adoption of existing technology to its coke ovens will permit the Japanese steel industry to increase the amount of new and/or weak coking coals in its coke oven charge from the 1990 industry average of 16.7% to 20% by 1995, and 25% by 2000 where it will hold to 2005. It is expected the rest of the western world will not increase its present usage of non-coking coals. By 2005, Germany is forecast to have in-place coke capacity of 4 mtpy in Jumbo reactors capable of using 80% non-coking coal in the blend. These forecasts translate into the following reduction in coking coal consumption. (Table 12.1.1)

Table 12.1.1			
	1995	2000	2005
	(million tonnes)		
Japan	1	3	3
Total Western World	1	3	8

12.1.4 PULVERIZED COAL INJECTION (PCI)

The injection of fuel into the blast furnace to reduce coke consumption has been widespread for some time. Natural gas, fuel oil and non-coking coals have been the dominant materials

used. While coal injection requires considerably higher capital cost, for operating and technical reasons it is concluded that coal will dominate in the future.

The oil crisis caused a great upsurge of PCI in the 1970s. Interest has been recently increased because of the shortage of cokemaking capacity in the strong steel market.

On the short term, PCI is the major threat to coking coal. The steel industry worldwide is considering PCI as a vehicle to overcome the serious problem of aging coke batteries. Increasing PCI ratios permit integrated steel producers to continue to make hot metal without replacing cokemaking capacity.

While it appears that the technical limit for coal injection may be as high as 400 kg/thm¹, 300 kg/thm is a realistic limit. 300 kg/thm represents a 60% reduction of the current coke rate of approximately 500 kg/thm, assuming a coke replacement ratio of 1 t coke per 1 t PCI. Above a PCI rate of approximately 150 kg/thm, oxygen enrichment of the blast air is necessary.

This study forecasts the following industry average PCI rates. (Table 12.1.2)

Table 12.1.2			
	1995	2000 (kg/thm)	2005
Japan	150	200	300
Western World	80	120	175

If these rates prevail, by 2005 Japan will consume approximately 65% less coking coal than if the 1991 average coking rate of 460 kg/thm had prevailed. The corresponding figure for the western world is 35% less coking coal.

12.1.5 NEXT GENERATION STEELMAKING TECHNOLOGY

Three new steelmaking processes are under extensive study in Australia (HISMelt), U.S. (AISI-DOE) and Japan (DIOS). In addition the Corex process is in commercial operation in South Africa.

All four processes have in common the use of non-coking coal in a reactor to make hot metal directly from iron ore.

While the Corex process is commercially proven, it will likely have little major long term impact. The integrated producers are pinning their hopes on one of the other three approaches.

The timing for adoption of this new technology will be tied to the effective operating life of each individual steel company's coke battery and blast furnace capacities. The industry expects the technology to be ready in the 2000-2005 period and will likely be integrated into operations starting about 2005.

One Japanese source expects the "next generation" of steel capacity to include a mix of 30% electric furnace, 20% new technology and 50% conventional coke oven/blast furnace.

This study assumes the impact of new technology on coking coal requirements will be 3 mtpy of hot metal made by the Corex process forecast to be on stream by 2000. This represents a loss of 2 mtpy of coking coal. Should 20% of Japan's crude steel production in 2005 be by new technology, a reduction in coking coal of a further 4 mtpy (at the then forecasted coke rate 160 kg/thm) would result.

12.1.6 COKE QUALITY

Some experts believe that as coke rates are decreased by PCI rate increases, the remaining coke will have to be of much higher quality. This, in turn, will increase the desirability of B.C. type coking coals. Others argue high quality coke will not be required. The issue remains to be resolved by testwork.

12.1.7 OPPORTUNITY

The U.S. steel industry is forecast to enter a serious coke shortfall situation in the mid-1990s when aging coke batteries must close. The total world integrated steel industry faces the same situation but to a lesser degree. The production of coke in B.C. for export to the U.S. mid-west and to markets in the Pacific now supplied by Japanese coke makers may merit serious consideration. A new oven design developed in the U.S. that minimizes capital cost and pollution problems by having no by-product recovery may be an attractive option.

If the forecast of greatly expanded electric arc furnace capacity is accurate, increasing amounts of DRI (direct reduced iron) and/or iron carbide will be required. Both commodities utilize

1 tonne hot metal

amounts of DRI (direct reduced iron) and/or iron carbide will be required. Both commodities utilize natural gas (or coal) and iron ore in their manufacture. Production of these in B.C. should be evaluated as should a mini-mill incorporating thin sheet casting.

12.1.8 CONCLUSIONS

Table 12.1.3 summarizes the coking coal reduction that might be experienced in both Japan and the total western world from changing coke and steelmaking technologies. The quantities represent the reductions in coking coal consumption that would occur relative to the situation had 1990 conditions prevailed. Japan could be using approximately 35 mtpy less coking coal by 2005; the western world, 165 mtpy less.

The two most significant changes are wider application of PCI and expansion of minimill capacity because of thin sheet casting. PCI is more significant in the short term; thin sheet casting, in the long term. Ultimately the new generation of steelmaking technology will dominate.

The above forecasts are quite crude, but are sufficiently accurate to indicate that changing technology will put severe downward pressure on coking coal demand and, by implication, on price.

There is no single innovation under consideration by the steel industry that does not have as a major objective, the reduction of coking coal consumption per tonne of steel produced.

It appears very likely that the last integrated steelmill using coke and blast furnaces has been built, at least in the developed world. At best, coking coal can expect a flat demand in the future. Realistically, a sharp decline should be assumed in future planning by the B.C. coal industry.

12.2 Technological Factors Likely To Affect Thermal Coal Usage

The thermal coal produced in British Columbia is all consumed outside the province, 24 per cent in Canada and the balance offshore.

The following chapter deals with the growth in world demand for thermal coal; indeed it is the fastest growing market. The largest portion of this increased demand will be used to generate electricity.

Increasingly over the last 15 years concerns have been raised about gaseous emissions resulting from the burning of coal for power generation. Concern focused initially on the acid gases - sulphur dioxide and the oxides of nitrogen - but attention is now being turned toward emissions of carbon dioxide which many believe leads to significant warming of global temperatures as a result of an enhanced greenhouse effect. Some of these concerns are legitimate, while others are based on a lack of understanding as to how far new technology has advanced with respect to the utilization of coal.

Many perceptions are reinforced by the fact that a number of countries including Eastern Europe, China and some of the newly industrialized countries are not taking advantage of current or new technology which can reduce many of these emissions. Stories such as that contained in the National Geographic earlier this year, dramatically demonstrate the need for such countries to adopt known technology.

Table 12.1.3

Summary of Forecasted Reductions in Coking Coal Demand Relative to the Situation had Present Conditions Prevailed into the Future

	Reduced Coking Coal Requirement (million tonnes)		
	1995	2000	2005
Japan			
Increased electric furnace capacity	1	2	2
Changing cokemaking technology	1	3	3
PCI	15	17	25
New steelmaking technology	—	—	4
	17	22	34
Western World			
Increased electric furnace capacity	19	69	82
Changing cokemaking technology	2	3	8
PCI	38	46	69
New steelmaking technology	—	2	6
	59	120	165

It is very important for the future of many electric utilities that new cleaner coal utilization technology be developed. Coal is used for approximately 40 per cent of world-wide electrical production and Canada is no exception. Coal is widely used for power generation in Canada - 79 per cent of Alberta's electricity was generated by coal in 1990. Also heavily reliant on coal are Saskatchewan and Nova Scotia at 73 per cent and 60 per cent respectively; Ontario at 25 per cent and New Brunswick at 10 per cent.

As Canada's fossil fuel reserves are 48 per cent coal, this dependence on coal is unlikely to change in the future.

In western Canada we are blessed with low sulphur coal and the coal burning utilities have been guided by stringent environmental controls. However in order to meet the public's expectation of further improvement in emission control, the utilities are always striving to develop new, more efficient and cleaner methods of utilizing this abundant energy resource, coal.

With few exceptions, coal fired power generation makes use of pulverized coal firing. As most of the power plants have many years of life ahead, and with life extension many years beyond that, it can be immediately concluded that pulverized coal firing will remain the dominant coal technology for many years to come. However, this may not be the case if requirements for environmental control render older plants uneconomic or if technology change provides users with significantly lower costs.

When these facts, together with the needs of the current national and international environmental legislative programs, are taken into account, it is clear that new, cleaner coal technologies will be required if supplies of economically priced electricity are to be available in the future. Fortunately for us in Canada, several other countries are in a similar position and this has encouraged major programs of clean coal technology development in North America, Japan, and Europe.

The following discussion will centre on reducing the environmental impacts of coal by means of the so-called "clean coal technologies", describing a number of these technologies and indicating the breadth of work and opportunities available for the future.

Many of them promise a great improvement in efficiency and environmental cleanliness but at the present stage of development appear to be more expensive than conventional coal burning technology, while others, under site specific conditions, are now either economically viable or are approaching economic viability.

Clean coal technology is taken to mean those coal utilization technologies which significantly reduce the amount of gaseous, liquid and solid emissions to the environment while generating electricity from coal.

"Clean coal" power generation technologies which will be coming available over the next 25 years can be grouped as follows:

Developments in conventional power generation:

- pulverized coal firing; and
- atmospheric fluid bed combustion.

Advanced coal utilization technology:

- pressurized fluid bed combustion;
- integrated gasification combined cycle;
- integrated gasification fuel cells;
- advanced hybrid cycles;
- magnetohydrodynamics; and
- direct coal fired gas turbines.

Developments of Conventional Power Generation

Since about the early 1970s, a range of technologies have been developed which reduce the emissions produced by conventional coal fired boilers. These can, for convenience, be grouped as in-furnace controls and flue gas controls. In furnace controls include low NO_x combustors, re-burning, sorbent injection and advanced slagging combustors. Low NO_x combustors are now commercial while the remainder are still in the demonstration phase.

Flue gas control technology includes duct injection and humidification, selective catalytic reduction, non-selective catalytic reduction, scrubbers for sulphur dioxide and, finally, combined flue gas clean-up. Selective catalytic reduction (SCR) and scrubbers for sulphur dioxide are both currently commercial, while the remainder are currently being demonstrated. SCR is used in Germany and Japan, but not in North America. The

purpose of all of the foregoing pulverized coal firing technologies is to reduce NO_x and SO_x .

Another method of reducing NO_x and SO_x in conventional power generation is through "atmospheric fluid bed combustion" which has made rapid progress over the last 15 years with in excess of 2500 fluid bed boilers estimated to be in operation around the world.

In Canada, a two unit bubbling bed plant was installed at C.F.B. Summerside, PEI in 1982, and New Brunswick Power installed a demonstration unit using circulating bed technology at Chatham in 1986. At Point Aconi, N.S., Nova Scotia Power is now constructing, for start up in early 1993, a 165 MW plant which will be the largest circulating fluid bed power plant in operation.

Advanced Coal Utilization Technology

There are a number of advanced coal technologies under development which not only promise major reductions in emissions, but also offer the opportunity to increase the efficiency of energy conversion from current levels in electrical generation of 37 to 38 per cent in the developed countries to 50 to 60 per cent over the next twenty-five years. These technologies include pressurized fluid bed combustion, integrated gasification combined cycle, integrated gasification fuel cells, advanced hybrid cycles, magnetohydrodynamics and direct coal fired gas turbines.

Table 12.2.1, "Advanced Coal Utilization Technology", summarizes the potential performance of these technologies in terms of emissions and energy conversion efficiencies (cycle efficiency). Likely dates of commercialization are also included.

No attempt has been made to provide a technical description on these various clean coal technologies in this chapter. For those interested, a technical summary of each process is included in Appendix B, "The Impact of Clean Coal Technology on the Use of Thermal Coal in Electric Power Generation".

To address the environmental concerns related to coal, The Coal Association of Canada has initiated an IGCC demonstration project with the support of many of Canada's electric utilities and coal supply companies who are committed to accelerating the introduction of this clean coal technology in Canada. The Coal Association's IGCC demonstration project has the goal of designing and building a commercially sized IGCC power plant in Canada to demonstrate the viability of such a plant under the conditions unique to Canada; e.g., use of Canadian coals, and severe winter conditions.

The IGCC demonstration project will be carried out over a five-year schedule starting with a feasibility study and selection of a site. This process is now under way. The project will be

Table 12.2.1

Technology ¹	Emission Reduction % ²		Cycle Efficiency %	Commercialization Date
	NO_x	SO_2		
PFBC	~ 75	~ 90	40 - 42	1995
IGCC	~ 80	To 99	41 - 45	1997
IGFC	99+	99+	45 - 58	2010
Advanced Hybrid Cycles ³	~ 80	To 99	40 - 45	2000
MHD	~ 80	~ 95	50 - 60	2015
Direct Coal Fired GT	80+	80+	43 - 48	2010

Note: 1. PFBC: Pressurized Fluid Bed Combustion
 IGCC: Integrated Gasification Combined Cycle
 IGFC: Integrated Gasification Fuel Cell
 GT: Gas Turbine.
 2. Approximate reduction based on conventional coal fired power plant, no add flue gas cleanup.
 3. Cycles based on partial gasification of the coal combustion of residue in atmospheric or pressurized fluid bed boilers.

carried out in three phases: Phase 1 consists of a technical feasibility study, Phase 2 consists of detailed design and cost estimation, and Phase 3 consists of construction and operation. Phase 1 is being supported financially by many of the member organizations of The Coal Association of Canada, including five electric utilities. Support has also been obtained from both the federal and provincial governments under the Western Low-Sulphur Coal to Ontario program and the Province of British Columbia.

The feasibility study, which will require approximately a year to complete, is now under way. It consists of two stages. Stage 1 will determine an appropriate site in Alberta or Saskatchewan. Discussions of site selection have shown that there are several promising sites in Alberta and Saskatchewan. Final selection of a site will depend on the outcome of the feasibility study and on more detailed assessments of the requirements for additional power by the electric utilities involved. Stage 2 is the conceptual design and cost estimates. It includes selection of the gasification process, selection of a gas turbine, design of the gasification and gas clean-up systems, and design of the combined cycle power plant. Plant cost estimates will be an important output from the study.

Some major decisions have been made in relation to the plant design. The Shell gasification process and the General Electric 7F advanced gas turbine are the two major components already selected. The turbine is rated at approximately 170 megawatts for this application site and design temperature.

The basis of the feasibility study is a prairie mine mouth plant site, similar to TransAlta's Keephills plant, using coal from TransAlta's Highvale Mine west of Edmonton. Sensitivity cases will also be evaluated for Saskatchewan lignite and a B.C. bituminous coal. Two other cases are also being evaluated: a remote gasifier providing clean gas by pipeline to an existing power plant located in Edmonton, and a variation of the base case in which 50 per cent of the carbon dioxide produced will be recovered as a source for enhanced oil recovery.

It is anticipated that acid gas emissions from the plant will be reduced to very low levels, with sulphur captures of 98 per cent expected. The

plant efficiency will be significantly greater than for a conventional coal fired plant, particularly given the low level of emissions. This has the benefit of reducing the carbon dioxide emissions per unit of electrical output. It is hoped that the study will lead to the detailed design stage and result in an early Canadian demonstration of this promising clean coal technology.

Coal gasification and IGCC are technologies which provide electric utilities with many advantages over conventional power generation. Reduced water needs, faster construction times and smaller economic plant sizes are all important, but major reductions in the emissions of sulphur dioxide and NO_x are likely to be the most important considerations.

The promise of higher efficiency combined with a reduction in other environmental impacts is making IGCC coal based technology the choice for many utilities in North America and overseas. Future development of advanced fuel cells will reinforce this trend and enable significant reductions in per unit CO_2 emissions to be made.

Sulphur and nitrogen oxide emissions, already shown in Germany and Japan to have been reduced by 75 to 80 per cent by existing technology, can be reduced close to zero. By introducing more efficient power generation cycles, unit carbon dioxide emissions will potentially be reduced by up to 40 per cent relative to typical current carbon dioxide emissions. These technologies will be approaching commercial use by the late 1990s, and be in use by 2020.

There are numerous clean coal technologies available now and for the future that reduce the impact of coal-fired electric power generation on the environment.

Coal is and will be for the foreseeable future, an important fuel source for the generation of electric power in Canada and around the world. However, as population growth and the improvement of living standards place an increased strain on world power supply, the general public must be educated to recognize that coal, through the options now made available by technological development, has the potential to meet the demand in a manner that is environmentally responsible.

13. WORLD COAL TRADE 1990 TO 2010

In this chapter the terminology of "world coal trade" has been adopted as it more accurately reflects the total trade in coal between countries than does the "seaborne coal trade". The difference between world coal trade and seaborne coal trade is world coal trade is based on all imports and exports between countries of the world. It includes those continental movements of coal by railway such as in Europe and the eastern bloc countries. Although seaborne trade reflects the majority of coal volumes traded between countries, it is restricted to that coal trade requiring ocean transport. (Table 13.1)

Forecasting is an inexact science at best and in an attempt to portray as realistic and comprehensive a position as possible for the purpose of projecting into the future, it was decided to examine coal export-import requirements.

Chapter 9 pointed out that 1990 was a significant year in world coal trade in that total

tonnage of seaborne thermal coal exceeded metallurgical coal for the first time. It is believed that this situation will not reverse itself and thermal coal use will far surpass that of metallurgical coal during this forecast period and well beyond.

In the year 2010 it is predicted that thermal coal will exceed metallurgical coal in world trade by a factor of 3 to 1.

Coal, whether it is used to make steel, raise heat or generate electricity, is a component of the world energy scene. Even though coal will continue to have non-energy uses, these will be minor in terms of total volumes used. Thus in all cases coal will be treated as energy.

In the past there has been extensive debate as to whether or not there is a relationship between the price of oil and that of coal. With the advent of thermal coal requirements exceeding that of metallurgical coal on an ever increasing basis, the writer believes that the price of competing energy sources will be a more dominant factor in the future.

Coal is ubiquitous compared with crude oil. Despite current environmental concerns which are already being addressed, the world will once again recognize the importance of coal resulting in increased expectations with respect to coal's role as a stable energy source at competitive costs. The current coal market is very stable in price and for the moment appears to be independent of oil prices.

In examining the role of coal in the future, there are a number of factors to be considered:

1. Demand for steel remains relatively flat during the forecast period and changing technologies result in less metallurgical coal being required.
2. Primary energy consumption will rise with the fastest growth in demand occurring in the developing countries.

Table 13.1

World Coal Trade vs. Seaborne Coal Trade 1980 to 1990 (millions of tonnes)

Year	World Coal	Seaborne Coal
1980	256.2	189.6
1981	271.3	205.1
1982	269.2	206.2
1983	266.0	197.2
1984	304.7	235.0
1985	335.8	275.5
1986	336.1	275.1
1987	340.9	283.1
1988	375.7	302.9
1989	381.7*	317.0
1990	403.6*	330.0*

* estimated tonnages

Sources: International Bulk Journal
Chase Manhattan Bank

3. Oil and natural gas consumption will rise but their share of total energy use will decline.
4. Primary energy consumption will rise more slowly in the highly industrialized countries due to energy conservation and efficiency efforts.
5. The greatest growth in oil consumption will be in the less developed countries as they strive to create an industrial base. At the same time many of these same countries are committed to coal-fired electricity generation. Ambitious plans are under way for industrial expansion in basic energy intensive industrial expansion such as steel manufacturing.
6. Energy and environmental issues are becoming increasingly inseparable and both will become more of an international issue. It is going to have to be recognized that issues such as global warming cannot be solved by a single country acting alone. A greater understanding and coordination in addressing these issues is required.
7. The vast majority of oil reserves are concentrated in the Middle East. Over 65 percent of the world's crude oil reserves are to be found in the Persian Gulf in contrast to the coal reserves which are distributed more evenly on most major continents around the world.
8. The use of nuclear energy will continue to increase. Nuclear power is perceived by some countries as making them more independent and it is clean burning. However, public opinion stands strongly against further development until some critical problems are resolved. These include safety, heavily loaded costs in the development phase and also in decommissioning. Radioactive waste disposal is also a concern.

Nuclear power usage is one of the more difficult to forecast because although advances with respect to safety are being made, another nuclear power plant disaster, anywhere in the world, will set the nuclear industry back a further ten to twenty years. Despite claims made by proponents, when

one considers the number of nuclear plants currently existing in the world, the age of some of these plants, varying safety standards and finally the human factor, it is not unreasonable to expect a major incident to occur. Of probably more significance is the fact that, with many large nuclear generating plants reaching middle age, the enormous, and unanticipated, costs of capital replacement to maintain their safety of capability, are making them much less economic than originally expected.

9. If coal is going to assume the growth anticipated, technological advancements in how it will be utilized must be achieved. In other words, utilization of coal will have to be accomplished in a much cleaner manner.
10. The principal reason why world coal trade is expected to increase are:
 - Poland, the United Kingdom and West Germany are expected to reduce their exports.
 - The anticipated elimination of coal production subsidies in Europe.
 - More opportunity for Western countries to export to the former Eastern bloc countries.

13.1 Metallurgical Coal Trade

Dr. H. N. Halvorson's report on "Impact of Changing Coke Making and Iron Making Technology on Coking Coal Demand" (Chapter 12.1) presents an excellent overview of the technological changes taking place in the steel making industry around the world.

The results shown are not particularly good news for the coal producers of British Columbia in that they will be directly impacted by the reduced volumes of coke required, not just in Japan, our principal market, but in the world as a whole.

It is, however, very important to recognize changes taking place in the marketplace and to adjust accordingly. Of equal importance is to identify trends that are occurring in order to identify business opportunities for the future. Certainly as we look forward to the 21st century, there are interesting regional trends taking place in coal.

In Europe, for instance, Poland's exports are expected to decline substantially from current levels of 10 million tonnes to virtually no metallurgical coal exports past 2005. Although Poland's coal reserves are still plentiful, geology poses problems and the average depth of the mines continues to increase beyond 1700 feet. Production costs are subsequently increasing and elimination of subsidies is being considered, all of which lead to less exports.

West German coal production is also heavily subsidized and in anticipation of European economic unification by 1992, the EEC has requested the West German government develop a plan for reducing and eventually eliminating subsidies on coal production. There will be social problems to be resolved resulting from such action; however in the long term the removal of subsidized coal production around the world has to be viewed positively.

Western Europe's demand for metallurgical coal is relatively flat during the forecast period, but imports will increase slightly due to loss of domestic supplies. This event will be brought about on the assumption that the impact of Germany not having to use domestic metallurgical coal will not be felt until after the year 2000. Overall demand for metallurgical coal in world trade will decline even though developing countries will require more steel as they industrialize. A combination of the factors identified by Dr. Halvorson will restrict growth in coal demand.

Japan's steel industry is expected to decline due to decreasing domestic demand and increased competition with respect to steel exports. Asia will continue to have the largest market for metallurgical coal.

The demand for the low to medium volatile coals produced in the province will decline substantially over the next twenty years. This trend to reduced consumption of low volatile metallurgical coal has been clearly identified; however, there are so many variables involved that it is difficult to be precise on forecasts that exceed a ten year time frame. The numerous forecasts that have been made for future metallurgical coal requirements vary extensively. For this reason and for the purpose of this report, it was decided to use a range of forecasts in increments of five year periods.

The following tables have been developed using the high and low levels of various forecasts with the median representing the mid point in each case.

Table 13.2 indicates the range of the high and low estimates for the consumption of imported metallurgical coal in the western world. The median level indicates a reduction in demand of 23 per cent between 1990 and 2000 with a further reduction in demand of 12 per cent between 2000 and 2010. This results in an overall reduction in world coal trade of metallurgical coal of some 55 per cent between 1990 and 2010 or a reduction of 88 million tonnes per year in 2010 compared to 1990.

Table 13.2

**Forecasted
Western World Consumption of Imported
Metallurgical Coal For Coke Manufacture
1990 to 2010
(millions of tonnes)**

	1990	1995	2000	2005	2010
High	160	156	145	145	130
Low	160	125	110	101	95
Median		140	127	123	112

Obviously the further the projections extend into the future, the less reliable they become. However, a definite trend is obvious and that is that the demand for good quality metallurgical coal for making coke is on the decrease. This is particularly true in Japan where reduced requirements are more severe, as indicated on Table 13.3 where a 54 per cent reduction occurs at the median level between 1990 and 2010. This is due to the

Table 13.3

**Forecasted
Japanese Consumption of Imported
Metallurgical Coal For Coke Manufacture
1990 to 2010
(millions of tonnes)**

	1990	1995	2000	2005	2010
High	61.4	62	55	50	46
Low	61.4	30	22	14	10
Median		45	38	32	28

use of new technology and the age of both coke ovens and steel mills. A lower domestic steel demand and a loss of their competitive edge in steel making will force Japan into the use of new technologies earlier than other countries.

British Columbia exports of metallurgical coal to Japan in 1990 totalled 12.7 million tonnes. Therefore if Japan were to maintain its ratio of supply sources by volume, by the year 2010 British Columbia exports of low to medium volatile metallurgical coal to Japan could be as low as 6.7 million tonnes. Whether or not such volumes would come about is a moot point for discussion, but these levels do reflect current forecasts.

Offsetting this decrease in metallurgical coal for coke manufacture is an increase in the amount of coal required for pulverized coal injection. Imports of coal for PCI to 2010 are shown in Table 13.4 which indicates a 240 per cent increase over 1990 or a 24 million tonne increase in the western world. Table 13.5 indicates a 215 per cent increase in pulverized coal injection in Japan in 2010 or a 8.2 million tonne increase over 1990.

Even with this offsetting tonnage, the reality of the situation is that at the median level,

Table 13.4

**Forecasted
Western World Consumption of Imported
Coal For Pulverized Coal Injection
1990 to 2010
(millions of tonnes)**

	1990	1995	2000	2005	2010
High	10	23	32	34	36
Low	10	20	28	30	32
Median		21.5	30	32	34

Table 13.5

**Forecasted
Japanese Consumption of Imported
Coal For Pulverized Coal Injection
1990 to 2010
(millions of tonnes)**

	1990	1995	2000	2005	2010
High	3.8	8.0	12.0	14.4	16.0
Low	3.8	6.0	7.0	7.8	8.0
Median		7.0	9.5	11.1	12.0

the impact of requirements for metallurgical and PCI coal combined in 2010 for the western world is 24 million tonnes or 14 per cent less than at present. (Table 13.6)

Table 13.6

**Forecasted
Western World Consumption of Imported
Metallurgical Coal and PCI Coal
1990 to 2010
(millions of tonnes)**

	1990	1995	2000	2005	2010
High	170	179	177	179	166
Low	170	145	138	131	127
Median		161.5	157	155	146

For Japan the corresponding reduction is 22.1 million tonnes or a 33 per cent reduction. (Table 13.7)

Table 13.7

**Forecasted
Japanese Imports of Metallurgical Coal For
Coke Production and PCI Coal
1990 to 2010
(millions of tonnes)**

	1990	1995	2000	2005	2010
High	65.2	70	67	64.4	62
Low	65.2	36	29	21.8	18
Median		52	48	43.1	40.0

To date Canada has not supplied any coal for use as PCI. The reason for this has been a combination of coal quality and price. There is not a consensus among steel makers around the world as to the ideal coal for pulverized coal injection. There are many variables including coke composition and operating characteristics of individual mills. The fact remains, however, that if the British Columbia producers wish to capture a share of the market, they will have to be aggressive and also examine other sources of coal in the province.

13.2 World Thermal Coal Trade

World demand for thermal coal is on the threshold of a major expansion of unprecedented proportions. Never before in the history of the

industrialized world has a situation occurred where such a massive volume of a commodity been in demand. Fortunately the world's resources of coal are plentiful and are sufficient to meet the projected demand.

Although there is cause for optimism, caution about becoming overly euphoric is urged. There continues to exist in society today a deep rooted scepticism about the use of coal and in order to capitalize on the opportunity, these fears will have to be put to rest. It should also be remembered that although there is good evidence to substantiate the projected growth in demand for thermal coal, it is still a forecast and forecasts are notoriously incorrect. One only has to look back a few years to remember the huge projections that abounded during the 1970s for a doubling in demand for steel in Japan with consequential unbelievable growth in demands for metallurgical coal that failed to materialize. Or about the forecast increases in oil prices of the same time when figures of \$100 per barrel and more were being suggested.

In any event even if the projections for the growth in demand for thermal coal are out by 50 per cent, the increase is still of major proportions.

This increase in demand results from an ever increasing population base and the electrification of the world's lesser developed countries. Most of the total growth for thermal coal will be for the generation of electricity. In terms of world coal trade the growth will be strongest in the Pacific Rim and Europe, but for different reasons. In Europe it is anticipated that increased imports will be required to replace the indigenous production from costly and sometimes inefficient mines that are often subject to enormous subsidies.

Much of the coal used in Europe for electric power generation is low quality and until such times as new technologies are put in place to combat the undesirable emissions resulting from burning this coal in its raw state, imports of higher quality clean burning coal will be required.

Like the forecasts for metallurgical coal, those for world trade in thermal coal vary considerably. However, the range between forecasts is not as extreme as that for metallurgical coal. Consequently only the median figures are included in the following tables. Table 13.8, World Thermal Coal Imports and Table 13.9, World Thermal Coal

Exports have been derived from a number of published reports and information supplied by personal contacts in the industry, including both importing and exporting countries.

World wide imports of thermal coal are estimated to increase by 270 per cent between 1990 and 2010. Growth in imports (Table 13.8) is most pronounced in Europe during the forecast period. This increase is due to the privatization of electric utilities in Great Britain along with a constant growth in demand for electricity in all of Europe. The anticipated removal of coal production subsidies and concern for the environment also contributes to this very dramatic increase in coal import demand.

The second most active area of growth in

Table 13.8

**Forecasted
World Thermal Coal Imports
1990 to 2010
(millions of tonnes)**

	Europe	Asia	Latin America	North America	Total
1990	116	78.5	1.3	12.6	208.4
1995	155	110	2.0	9.0	276
2000	191	152	4.0	14.0	361
2005	265	185	7.0	17.0	474
2010	315	214	12.0	22.0	563

Table 13.9

**Forecasted
World Thermal Coal Exports
1990 to 2010
(millions of tonnes)**

Exporters	1990	1995	2000	2005	2010
Australia	46.8	78	91	118	137
United States	39.0	51	96	157	194
South Africa	43.0	54	61	74	93
Poland	19.3	20	15	4	4
Canada	5.6	15	17	21	24
China	13.4	19	25	34	40
South America	20.0	28	42	51	55
U.S.S.R.	20.5	7	7	6	5
Other*	6.3	8	12	15	16
Total	213.9	280	366	480	568

* Includes West Germany, Indonesia and Great Britain

thermal coal demand will be in the Asian countries of the Pacific Rim. Coal requirements over the next twenty years are projected to increase by 273 per cent from 78.5 million tonnes in 1990 to 214 million in the year 2010. Japan leads the Asian countries representing 45.8 per cent of the imports into Asia in 1990, 44.7 per cent in the year 2000 and 46.7 per cent in 2010. Table 13.10 is a projection of Japan's imported thermal coal requirements 1990 to 2010.

Table 13.10			
Forecasted Thermal Coal Requirements in Japan By Source 1990 to 2010 (millions of tonnes)			
	1990	2000	2010
Australia	22.0	47.5	70.0
South Africa	2.5	3.0	5.0
China	3.5	3.0	4.0
United States	2.7	5.5	10.0
U.S.S.R.	2.5	4.5	5.0
Canada	2.0	2.0	2.0
Indonesia	0.5	1.5	3.0
Colombia & Others	0.3	1.0	1.0
Total	36.0	68.0	100.0
Data Base: NCA Coal Voice Mitsubishi			

On the supply side the traditional producers of export coal will meet most of the demand. A country's ability to export is a function of a number of variables including:

- **Domestic demand.** Some exporting nations such as the United States, China and Australia have large coal requirements of their own and only the excess over their own demand can be exported. Other countries such as Colombia and Venezuela have little domestic requirement at present.
- **Location of reserves.** In order to maximize the opportunity to deal in the international coal trade, location of a country's coal reserves is important. The proximity to ocean terminals has a major impact on coal export costs.

- **Productive capability.** In order to be successful in the export market, particularly in thermal coal, the quality of the resource is paramount because in essence one is selling heat. A combination of good quality coal amenable to low cost mining is the most desirable. Should proximity to tidewater, quality and low cost mining conditions not all be available, then the country would only be able to serve specific and limited markets.

In addition to the traditional exporters of thermal coal, China, Colombia, Venezuela and Indonesia will play an increasingly more dominant role in the years ahead. China, despite its enormous appetite for coal as both the world's largest producer and consumer, is expected to become the world's fourth largest exporter of coal.

The United States has historically been the swing supplier in world coal in spite of being one of the higher cost producers. This is primarily due to its ability to supply large volumes of coal on relatively short notice. This position will be further enhanced should the proposed major expansion of the Los Angeles coal terminal and proposed increases in Alaskan coal production come to fruition.

Australia, the United States and South Africa will likely continue to dominate the supply of thermal coal to the international market.

The United States and South Africa are best positioned to be the leading suppliers into Europe with South America playing a lesser but important role. Australia will be the dominant supplier in Asia followed by the United States, China, South Africa and Russia.

On a world basis the United States is expected to dominate the export scene capturing better than 30 per cent of the projected world coal trade by 2010. Australia will be second at about 24 per cent followed by South Africa at 16 per cent.

Canada has never had a strong position in the thermal coal export market. Most of the country's low cost thermal producers are on the prairies supplying the domestic market with sub bituminous and lignite coals. Only three bituminous coal mines have been developed to supply the export market, two in Alberta and one on Vancouver Island in British Columbia. The remaining coal

shipped offshore is produced in conjunction with metallurgical coal in British Columbia or is excess to local requirements as in Nova Scotia.

Other than supplying current contracts, Canada has not been pursuing thermal coal offshore markets, mainly because of current price levels. However, this can change in the future. It is interesting to note in comparing various forecasts how Canada's potential is viewed differently around the world. Should Canada choose to become more active in thermal coal, the obvious market is Asia. And yet when you examine Japanese forecasts, Japan being the largest importer of thermal coal, they do not look for Canada to be a dominant supplier. This is reflected in Table 13.10. On the other hand other forecasts, including our own, recognize a greater opportunity for Canada with a projected share of 4 to 5 per cent of world thermal coal trade in 2010.

This can only mean that Canada's and British Columbia's capacity to participate in this market has not been recognized. Such a position probably results from a number of factors, the most important of which is current price levels. On the other hand, this market has never really been aggressively pursued as such and therefore potential customers have not paid that much attention to western Canada. This situation could change as the market matures.

13.3 Anthracite Markets

Current world production of anthracite is 290 million tonnes per year produced by some twelve countries. (Table 13.11) Of this total volume only 14 million is committed to the world coal trade. (Table 13.12 and 13.13)

The world's largest consumers of anthracite are China, U.S.S.R., North Korea, South Korea, Germany, South Africa, Spain, Vietnam and the U.S.A. Most of the anthracite consumed is in the developing countries for domestic purposes for heating and cooking although increased volumes in these same countries is being used in steel plants and for power generation. Anthracite is also used in carbon electrode plants, aluminum smelters and non-ferrous smelters. Processing facilities include briquette manufacturing, filter anthracite, calcining plants and activated carbon manufacturers.

Table 13.11

World Anthracite Production 1989 (millions of tonnes)

China	157.0 e
U.S.S.R.	40.0 e
N. Korea	36.0 e
S. Korea	24.0
W. Germany	7.0
S. Africa	6.6
Spain	5.6
Vietnam	5.5
USA	3.0
Others	6.0
Total	290.7

e - Estimated

Source: Gulf Canada Resources Limited

Table 13.12

World Anthracite Exports 1989 (millions of tonnes)

China	1.9
S. Africa	4.5
W. Germany	1.2
U.S.S.R.	2.0
USA	1.3
N. Korea	0.5
Netherlands	0.4
Vietnam	0.4
UK	0.3
Australia	0.4
Swaziland	0.2
Belgium	0.2
Others	0.8
Total	14.2

Source: Gulf Canada Resources Limited

The largest market for anthracite continues to be for briquettes although the steel industry offers potential increased demand for sintering and in some cases for pulverized coal injection but here, price would be a major consideration.

Table 13.13

**World Anthracite Imports
1989**
(millions of tonnes)

Belgium	1.0
Portugal	0.8
Netherlands	0.8
UK	0.8
Italy	2.8
Japan	2.3
France	1.8
S. Korea	1.5
Canada	0.4
Yugoslavia	0.2
E. Germany	0.2
Bulgaria	0.1
Others	1.5
Total	14.2

Source: Gulf Canada Resources Limited

Anthracite coal trade is a very specialized area within the world coal industry. At present Canada does not produce any anthracite. There is an attractive resource in the Ground Hog – Mt. Klappan area of British Columbia but lack of infrastructure has hindered development.

Anthracite exports and imports are included in the world coal figures.

13.4 Projected Coal Requirements

Total future world coal trade is projected on the basis of imports requirements over the forecast period. Table 13.14 summarizes the

Table 13.14

**Forecasted
World Coal Import Requirements
1990 to 2010**
(millions of tonnes)

	1990	1995	2000	2005	2010
High	378.4	455	538	653	729
Low	378.4	421	499	605	690
Median	378.4	437	518	629	709

import requirements from 1990 through to year 2010. On a median basis total world import demand will increase by 330 million tonnes, a 92% increase over total 1990 world imports.

The possible additional export availability from existing and new mines is shown in table 13.15. This projection was compiled by the International Energy Agency and reflects information supplied by various countries. In the case of some of the projected new capacity for Canada, the input was reviewed and some of the potential developments are deemed questionable. Nevertheless the potential exists to develop new capacity in Canada when economic conditions justify the investment. No time frame is given for the planned new expansions. The information available in table 13.15 indicates potential identified new capacity of 213 million tonnes. Therefore an additional 117 million tonnes of new production will be required over that identified through to 2010.

This total increase in world coal trade is large by any standard.

Table 13.15

Possible Additional Export Availability From Existing And New Mines
(millions of tonnes)

	Firm Existing	Firm New	Planned Additions To Existing	Planned New	Total
Australia	3.6	12.3	10.0	93.4	119.3
Canada	1.4	1.0	-	10.5	12.9
Indonesia	-	11.0	-	5.0	16.0
Colombia	5.0	-	10.0	20.0	35.0
Venezuela	-	-	7.0	0.7	7.7
South Africa	-	-	0.8	3.5	4.3
Alaska	-	-	-	18.0	18.0
Total	10.0	24.3	27.8	151.1	213.2

Source: IEA Coal Information 1990

14. BRITISH COLUMBIA'S PRESENT AND FUTURE COMPETITIVE POSITION

In the preceding chapters current and future supply demand projections for world coal trade have been discussed. There are important trends taking place in the market that will impact British Columbia coal producers, the net result of which is going to be increased competition.

In order for the provincial coal producers to maintain the same percentage share of the international market they have enjoyed in the past, they will have to focus their attention in two specific areas:

1. As diminishing future requirements for hard metallurgical coal cause a tightening of this market due to increased use of pulverized coal injection, producers will have to become even more competitive.
2. With the increasing demand for thermal coal, the province's resource base of thermal coals need to be more closely examined. Recent price levels for thermal coal have provided only moderate incentive to pursue this market. However, with the changes taking place in the market for coal, it is believed that producers will be re-examining the opportunities in the export of thermal coal.

Assessing inter-country competitiveness on an overall basis is always a challenge because one is usually dealing with averages, estimates and a range of numbers. The bottom line is that any producer can compete when the sales income exceeds all his costs.

Technical factors affecting competitiveness in the coal industry are location of the mine with respect to the market, proximity to tide water, ease of mining (geological structure), available infrastructure, environmental standards, quality of coal and a good work force. Non-technical factors are government policy, social standards and stability of the country.

Obviously, any producer who has the best of all these factors is in an enviable position. Seldom does it occur that a producer has the benefit of ideal situations in all these categories. Thus, he has to take full advantage of his more favourable components to reduce the impact of those over which he has no control.

The International Energy Agency undertook an analysis of representative export costs for steam and metallurgical coal for the major exporting countries.¹ Tables 14.1 and 14.2 have been derived from this source.

The FOB range of costs for each country include the mine cash costs, a capital recovery charge (assuming a 15 per cent return on equity) inland transportation costs and terminal charges. Cash costs include all operating costs, taxes and royalties.

As can be seen from Table 14.1, export costs for metallurgical coal on a CIF basis, the United States is the highest cost producer for the Japanese market, followed by Canada. For the European market Canada is the high cost producer. Therefore only the more profitable Canadian producers, or those who can sell on an incremental basis, will be able to compete in the European market.

Table 14.2 provides the same information but for thermal coal. Here, once again the United States is shown to be the highest cost producer for the Japanese market followed by some of the Australian coals from New South Wales, with Canada coming third.

In the European thermal coal market, New South Wales, Australia and Colombia have the highest indicated prices, followed by Canada.

¹ Information was provided to IEA by IEA Coal Research and included the producing countries of Australia, the United States, Canada, South Africa and Colombia.

Table 14.1

Representative Export Costs For Metallurgical Coal
(1989 US \$/mt)

Country	FOB (range)	Japan CIF (representative)	Europe CIF (representative)
Australia			
Queensland			
Underground	44.00 – 54.00	52.80	57.80
Surface	31.00 – 56.00	57.30	62.30
New South Wales			
Underground	41.00 – 48.00	50.00	54.20
Surface	36.00 – 47.00	52.70	56.90
United States			
Central Appalachia			
Underground	45.00 – 58.00	65.50	56.00
Surface	54.20	71.50	62.10
Canada			
Surface	47.00 – 80.00	58.70	62.90
South Africa			
Underground	33.00 – 41.00	43.00	41.50

Source: IEA Coal Research/IEA Coal Information 1990

* 1989 Exchange Rates:

Australia	1 US \$ = A \$	1.30
Canada	1 US \$ = C \$	1.18
South Africa	1 US \$ = R	2.50

One must be cautious in interpreting this information, as it only reflects approximations. The volumes sold are not calculated on a weighted basis; therefore the total costs could be somewhat distorted. The tables are useful, however, as they do give an indication of prices for the various countries. It cannot be determined how much coal is sold at market opportunity prices. The tables merely show the range of costs between countries. FOB prices for Japanese thermal coal purchases range from \$33.00 to \$42.00 (US) FOB; therefore little if none of the higher cost coals shown in Table 13.2 would find their way into this market.

Table 14.3 indicates contract prices for metallurgical coal being shipped to Japan for the years 1986 to 1990. Here again the USA as the swing supplier has the highest price, followed by Canada, the USSR, Australia, China and South Africa. For metallurgical coal destined for Europe (Table 14.4) the USA is also the high cost supplier followed next by Canada.

Turning to thermal coal destined for Japan (Table 14.5), Australia, the largest shipper, does not provide the lowest cost coal on a FOB basis. South Africa and Canada have the lowest selling prices. South Africa is also the lowest cost source of coal for Europe (Table 14.6) followed by Colombia and the USA.

Australia remains the world's leading coal exporter, although in 1989 the United States overtook Australia as the largest coking coal exporter. (Table 14.7) Metallurgical coal from Queensland, Australia and thermal coals from Queensland and New South Wales provide the bench marks for competition in both the Asian and European markets. For Canada it is the United States that is our main competitor even though Australia sets the basic competitive price.

South African coals are the lowest cost and therefore the lowest priced traded coals in the international market. Trade sanctions with South Africa has impacted their sales but they continue to be active in world trade.

Table 14.2

Representative Export Costs For Thermal Coal
(1989 US \$/mt)

Country	FOB (range)	Japan CIF (representative)	Europe CIF (representative)
Australia			
Queensland Surface	28.00 – 40.00	41.00	46.00
New South Wales Underground	30.00 – 45.00	53.80	58.00
Surface	34.00 – 60.00	53.40	57.60
United States			
North/Central Appalachia Underground	38.00 – 45.00	61.70	52.20
Surface	42.60	57.10	52.80
Southern Appalachia Surface	37.00 – 46.00	52.50	48.20
Utah Underground	55.00	65.00	N/A
Wyoming Surface	31.30	40.10	41.90
Canada			
Surface	37.00 – 45.00	51.40	55.60
South Africa			
Underground	22.00 – 31.00	34.40	32.90
Colombia			
Surface	49.80	N/A	57.40

Source: IEA Coal Research/IEA Coal Information 1990

* 1989 Exchange Rates:

Australia	1 US \$ = A \$	1.30
Canada	1 US \$ = C \$	1.18
South Africa	1 US \$ = R	2.50

The United States for some years has been the swing supplier as the Appalachian producers move in and out of the world coal market as prices rise and fall. The ability of the United States to act as the swing supplier may change with the enactment of the clean air legislation earlier this year. The demand for domestic supplies of low sulphur coals for electric power generation may curtail the export of this much coal. Such a situation could impact the pricing regimes of low sulphur thermal coal. Keeping this in mind, while Australia and South Africa are expected to remain the main suppliers of thermal coal to the growing Asian market, the United States could well expand its share as thermal coal prices become more competi-

tive but these volumes may be restricted due to domestic demand. The opportunity for Canada to participate would become more attractive under these circumstances.

In the preceding chapters we have attempted to provide an overview of the world coal trade and the trends that are taking place in both the metallurgical and thermal coal markets. The conclusions are that the market for metallurgical coal will undergo significant change from existing today and overall demand will be relatively flat. Meanwhile thermal coal demand is growing in world trade. Recent prices remain at depressed levels for metallurgical coal with some increases having occurred in the steam coal market. For the

Table 14.3

EXPORT METALLURGICAL COAL CONTRACT PRICES TO JAPAN
1986 – 1990
 (US \$/tonne FOBT)

COUNTRY	1986	1987	1988	1989	1990
USA	49.21 – 53.15	44.23 – 48.00	47.14 – 50.58	52.85	54.77
Australia	41.75 – 49.00	37.25 – 44.00	40.65 – 46.90	45.15 – 50.40	49.35 – 52.30
Canada	49.00	44.00	46.90	50.40	52.80
USSR	48.80	43.80	46.70	50.20	52.60
South Africa	38.88	33.88	37.63	42.13	43.95
China	42.00	36.00	38.90	42.40	44.80

Source: TEX Report / IEA

Table 14.4

EEC – METALLURGICAL COAL
IMPORT VALUES
1986 – 1989
 (US \$/tonne CIF)

COUNTRY	1986	1987	1988	1989
Australia	56.24	52.90	53.14	54.17
Canada	56.44	54.24	52.84	57.21
USA	59.46	56.85	57.28	58.44
South Africa	38.51	35.54	44.17	37.38
Poland	60.54	54.74	54.77	56.76
USSR	50.37	54.39	50.69	53.64

Source: IEA Coal Information 1990

short term supplies of both types of coal appear adequate to meet projected demand; however, new production capacity will be required after 1995. While coking coal prices are expected to increase reflecting cost and quality differences over steam coal, the differential in price between the two coals is expected to narrow as demand for thermal coal grows. Therefore some of the coal currently supplying the metallurgical market could find its way into the steam coal market.

Australia and South Africa will maintain their important position as thermal coal suppliers; however, the United States could also become the largest supplier although the impacts of the Clean Air Act in the United States may prohibit this at least in medium term. In international trade China, Colombia and Indonesia will play an increasingly

important role in thermal coal. Finally Canada has an opportunity to develop a niche in the thermal coal market. Thermal coal prices are expected to rise throughout the 1990s, although it is expected that Japan will use the Indonesian coal now coming onto the market place to keep Australian prices from escalating.

There is no shortage of coal in the world in terms of reserves. Thus it becomes a function of production capacity to meet projected demand. Consequently competition will remain at relatively high levels.

In British Columbia, whose trade is essentially based on the metallurgical coal market, there have been serious concerns about producers maintaining a competitive position. These concerns are well founded as reflected by the recent activity in properties changing ownership or management. On the other hand other producers are maintaining their competitive position albeit more marginal than in prior years.

Placing world coal prices aside there are a number of factors that influence a firm's ability to compete. The more important of these include:

- geography and transportation
- government policy
- taxation
- labour
- management

These are not listed in order of importance but each, either alone or on an incremental basis,

Table 14.5

EXPORT CONTRACT PRICES – THERMAL COAL TO JAPAN**1985 – 1990**

(US \$/tonne FOBT)

Year	Australia	South Africa	Canada	China
1985	49.44	32.45 – 34.50	35.85	40.44
1986	30.00 – 32.45	30.65 – 32.45	30.96 – 33.90	36.51
1987	29.40 – 30.28	24.50 – 27.23	30.22 – 32.50	29.51
1988	33.79 – 36.18	26.50 – 30.05	33.19 – 38.42	35.10
1989	37.10 – 40.32	31.33 – 34.45	35.25 – 41.73	38.90
1990	38.72 – 42.07	32.90 – 36.22	36.30	40.45

Sources: Nissho Iwai
TEX Report
IEA

directly impacts profitability and the ability to compete. These elements will be discussed in random order and will be related to the situation in British Columbia.

14.1 Management

Management in this context refers to corporate management and it has to be said that the coal industry in the province has experienced some outstanding, quality management from persons who not only look after their corporate responsibilities, but are concerned with the affairs of the industry and state of the province as well. At the same time the industry also has examples of mismanagement. It was interesting to note how in many cases where firms were experiencing finan-

cial difficulties, the cause could be traced back to a period when sound management decisions were not being made. Everyone is capable of making a mistake but poor management is an altogether different story.

In fairness to the coal industry, this situation is not symptomatic of coal alone. Every business has its fair share of poor managers. The point is made only to acknowledge that no enterprise, whether it be in the public or private sector is perfect. However, it is important to recognize past mistakes in an effort to avoid them in the future. The Canadian coal industry is currently blessed with competent management that is capable of dealing with the current issues.

Table 14.6

EXPORT CONTRACT PRICES – THERMAL COAL TO EUROPE**1985 – 1990**

(US \$/tonne FOBT)

Year	USA	South Africa	Colombia	Poland
1985	43.00	31.45	—	45.25
1986	39.85 – 41.00	27.50	31.50 – 32.00	39.00
1987	37.00 – 42.00	23.00	28.50 – 31.50	32.00 – 36.60
1988	43.00 – 45.00	25.90	31.00 – 35.00	41.90
1989	40.25 – 43.30	29.75	37.00 – 38.00	42.00 – 48.00
1990	42.90 – 46.10	31.00	40.00 – 41.50	50.00

Sources: Coal Week International
IEA

Table 14.7
**World Coal Exports
1989**
(millions tonnes)

Exporters	Thermal	Metallurgical	Total
Canada	4.2	28.6	32.8
USA	32.3	59.1	91.4
Australia	41.1	57.2	98.3
Other OECD	6.0	4.8	10.8
Poland	21.3	7.0	28.3
USSR	21.2	18.6	39.8
China	11.2	3.5	14.7
Colombia	12.7	0.3	13.0
South Africa	42.6	3.5	46.1
Non OECD	4.8	1.7	6.5
TOTAL	197.4	184.3	381.7

Source: IEA Coal Information 1990

14.2 Geography and Transportation

Even though the province's coal must be competitive at the ocean terminal or it would not be on the market, the fact remains that most of the provincial coal production requires a long inland transportation system. The railway and ocean terminals in British Columbia rate as some of the finest in the world in terms of efficiency and unit costs. They are certainly the tops in performance reliability. Despite this, inland transportation continues to be one of the producers highest cost elements. Coal is a major component of the railways total volume of goods transported. If this business is going to be maintained, the railways must be continually looking for ways to reduce costs either in equipment or total labour. The Canadian railways have done an outstanding job in moving the coal but they too must constantly be aware of the need for the industry to remain competitive. The railways also have to operate profitably, but they must be ever vigilant and proactive in searching for ways to reduce costs.

14.3 Labour Costs

It was interesting to note that in discussing the labour situation, all the coal companies in the province indicated a respect for the institution of unions. They all felt organized labour had an important role to play in the coal industry. Most

companies considered that better communication between management and the work force is desirable. In evaluating the impact of the labour component on the industry's competitiveness it became obvious the coal miners in British Columbia are some of the highest paid (combined wages and benefits) in the entire industry. This generation of miners enjoys a high standard of living that may not be passed on to the next generation. Over the years the various unions have been very successful in negotiating benefits for their members and there is no suggestion that these not be maintained.

Mixed reactions are received when the miners are questioned on the current state of the coal industry in the province. Most appreciate the seriousness of the current situation and are concerned about the future. Others think it is just a management ploy to force workers to take wage reductions.

Every mine and union interviewed mentioned that there had been poor management at various times in the past. At the same time most of the miners met with, including the union representatives, demonstrated a desire to work with management in making the mines more productive and indeed would welcome the opportunity to have input into the process. There was one point that frequently arose and that was that most miners enjoyed their jobs, they wanted to be proud of their occupation and the companies they worked for. All wanted to have a greater role in the decision making process. Addressing the issue of competitiveness, management also demonstrated a desire to work more closely with labour in seeking ways to become more proficient. Both sides seemed to feel that labour relations had moved forward a long way compared to the past. Only one union was critical of management and felt it was still working with attitudes from the last century. All unions except one recognized that becoming more active in the decision making process also brought an increased responsibility. If one wishes to assume authority, one also has to accept the responsibility that goes along with it.

Mention was made earlier in this section that the coal miners are highly paid. It should also be pointed out that this comment was not made in a derogatory manner. Each company recognizes that these levels were attained through the process of negotiation, and even with the serious state of

the industry there was not one reference to any roll back. However, both sides acknowledged that if this standard of living is to be maintained, overall productivity will have to improve even more. The easy improvements have already been made; the next ones will be a little tougher, but there exists a willingness to try.

It has to be recognized that in conducting a study of this nature, only a very small portion of the work force was met with and the most weight was placed on the views brought forward by the union representatives. Of the miners met with on a casual basis, all are concerned about the future of the coal industry and appeared genuine in wanting to work towards improving it. There were also those who feel the coal industry will continue to operate as it always has, no mines will close down and management were merely trying to get something for nothing.

In concluding this discussion on labour, there was an apparent concern over job security in the industry, a willingness in most cases to put what is past in the past, and to work more closely together to ensure a future. There was an indication there will always be a distinction between labour and management because the roles are different; however, he said the difference should not necessarily be confrontational.

14.4 Taxation

During meetings with the coal companies and the railways, the issue of taxes being a key component of their cost structure over which they have little or no control was raised by each. All conceded taxes were necessary, but at the same time they felt the levels where getting proportionately too high.

These taxes fall into three general areas:

- Municipal taxes
- Provincial taxes
- Taxes imposed by the federal government

14.4.1 Municipal Tax Levels

The following excerpt is taken from The Coal Association of Canada's 1990 Review of the British Columbia Coal Industry as a basis for discussion of municipal tax levels in the coal communities of the province.

"Communities supported by the British Columbia coal industry continue to exercise some of the highest per capita municipal spending rates in Canada. While the industry recognizes that a reasonable level of municipal spending must be maintained, certain municipalities have established and continue to build significant reserves. This is completely at odds with difficult cost-cutting measures currently under way at all coal operations. The general public and the provincial government must demand municipal financial restraint commensurate with the financial restraint already implemented by the industry."

This is a very blunt message and reflects the coal producers' concern about being able to remain competitive. The seriousness of this situation is emphasized by the fact that one coal company has requested permission to withhold their municipal taxes for the current year.

The coal producers in the province are under continued pressure to reduce costs in face of global competition and every cost reduction opportunity must be aggressively pursued. At the same time the industry recognizes that taxes are necessary to maintain certain levels of service provided by the coal mining communities. All of these communities have the coal industry as their primary revenue base. Consequently, the fortunes of the coal producers ultimately are reflected on the communities themselves.

Although all communities are faced with similar problems there are subtle differences between the southeast coal fields and the northeast.

In the southeast there are three communities that tie their economy to the coal industry, Fernie, Sparwood and Elkford. Cranbrook on a regional basis participates as the largest service centre and is the only city in the region. However, the mine employees pretty well all reside in the first three communities, or in close proximity thereto.

Early in the 1980s, the three communities, each of whom provided a base for the labour force, agreed with each other and the province as represented by the Ministry of Municipal Affairs, to create an "Industrial Tax Base Sharing Agreement". The participants are to be commended in taking this forward looking approach to resolving a complex issue.

In simple terms the industrial tax revenues produced by the coal companies are pooled into a single account. Each community then submits a requisition to the provincial government on the basis of criteria established by a formula. The provincial government then allocates funds to each community from the tax pool and also based on the agreed upon formula. The formula takes into account the work force residing in each community compared to the work force in each mine, per capita expenditures and a factor for each community's non shareable assessments.

On the whole this agreement appears to be working satisfactorily and was certainly well thought out in its development. The province does its best to ensure equitable treatment.

However, tax rates are established by the communities and are based on budget requirements. Therefore those communities with ambitious programs contribute to overall increases in the levels of taxation. The mines in the area all got together and made a presentation to the Elk Valley Communities. In this presentation they indicated that the level of taxation was higher than that required to maintain an adequate level of service. The companies prepared a thorough analysis which identified the Elk Valley Communities collect more than 2.5 times the revenue of similar sized communities in the province with the same situation existing in terms of expenditures. The mines made specific recommendations to the communities including an offer to assist in cost reduction initiatives.

Debt servicing is always a large component of the annual financing requirements; thus capital expenditure programs have a major impact on revenue requirements. This then becomes the balancing act for each council; that is, balancing the desires of the constituents which includes the mines with funds available. Like so many situations there are two sides to each story. In meeting with each community and the discussion of debt load came up, it was quickly pointed out that in the late 1980s and early 1990s when the Japanese were predicting huge increases in the demand for metallurgical coal, every mine asked the communities to develop more land and infrastructure for housing to meet the anticipated increase in the number of employees required to produce this additional coal. Each company wanted quality,

affordable housing available to attract a good work force. The communities proceeded with the capital expansions, but projected coal demand did not occur, leaving the communities with services and debt that were not required.

Another situation that occurs is individual companies often make substantial financial grants to the communities to assist in providing amenities such as recreational facilities. There is no intent to indicate whether this is right or wrong, but there is a downside; human nature being what it is, the tendency of the population then becomes to expect such gifts and some projects may be undertaken with a false sense of comfort in anticipation that the local mine will continue to support all projects with substantial financial contributions.

All three communities are fairly close together and should wherever realistically possible avoid duplication of amenities. This, of course, is easier said than done because there is pride of ownership and there should also exist a spirit of good natured rivalry. However, large capital expenditure items should be discussed jointly prior to proceeding.

The reason for this is the fact the capital for such facilities can usually be quite easily arranged; a problem generally occurs in the on-going operating costs. Even in large cities such facilities seldom pay their own way. What often happens is that for the first year or two of operation they have a high usage rate, but then usage falls off. There is a maximum as to how much the service charge can be, therefore the amount of subsidy increases as costs escalate. Cost recovery of such facilities range from 15% to 25% of total operating costs. A company must be careful not to promote services then express concern over increased local taxes.

An analysis comparing total tax revenue, total tax, revenue per capita, population and expenditures per capita of the three Elk Valley Communities and Tumbler Ridge in northeastern B.C. with all 147 communities in British Columbia has been compiled. The numbers on the Table 14.8 indicate the relative position with 1 being the highest and 147 being the lowest.

In terms of revenue per capita all four communities are within the top 10 per cent. In total tax revenues they are in the top 30 per cent and

Table 14.8

**COMMUNITY FINANCING
RANKING OF COAL COMMUNITIES WITH OTHER B.C. COMMUNITIES
TOTAL 147**

	Elkford	Sparwood	Fernie	Tumbleton	Edgemoor
Total Tax Revenue	48	54	55	42	
Tax Revenue Per Capita	3	12	17	4	
Population	81	66	63	68	
Expenditures Per Capita					
Recreation/Culture	25	3	44	6	
Transportation	46	65	12	78	

Source: Municipal Statistics 1989

with regards to population in the 42 to 55 per cent range of all communities.

Each of the communities recognize the serious situation facing the coal industry in the province and are naturally quite concerned. The impact had not hit the retail trade as of July 1991; however, many residents consider the current state of the coal business has the potential to become permanent. They all recognize their dependency on the coal industry and were all anxious to have input into the current hearings of the British Columbia Round Table on the Environment and the Economy.

Fernie relies to some extent on the tourist sector because of their well known ski hill. Elkford would also like to expand into tourism and is actively promoting the construction of the Kananaskis - Elk Valley highway which would provide quick access to the city of Calgary in Alberta. Many of the communities in British Columbia are looking to tourism to assist their revenue requirements. Beautiful as the province is, there are only a given number of tourists and all communities cannot expect to base their secondary industry on the tourist trade.

Dealing specifically with the levels of taxation for the southeast, one suggestion was that the tax sharing agreement should be monitored more closely. By being more sensitive to the current economic situation, it could go a long way to alleviating some of the problems currently being experienced. Recognizing the independence of each community, it was also felt that there is a role for some person or body to act as a facilitator in

discussing capital projects among the communities. The role would not be to approve projects and it may not prevent duplication, but at least when projects proceed all communities will be informed as to the rationale behind them. The communities should also take up the offer of the mining companies to provide assistance and guidance in cost reduction. This is not to infer that the communities are not capable in their own right because they are. Sometimes different viewpoints and good discussion leads to better results.

One observation that was continually coming forward is that improved communications between the companies and the community is required. People like to generally know what is going on. All the companies attempt to do this to some degree, but residents feel a better job could be done in this regard. The residents are not looking for a costly, glitzy program. Rather, a cost effective method of keeping people informed with current information. On the other side of the coin, the mines would like to be better informed of the spending plans of the communities and to have some mechanism for input prior to budgets being finalized and mill rates set.

In the whole matter of the relationship between the mines, the work force and the three communities, which are all intertwined, three observations came through loud and clear:

- There is a concern about the future of the industry;
- On the whole there exists a good relationship between one another; and

- There is an obvious need for improved two way communication.

In the northeast coalfields the town of Tumbler Ridge is primarily if not totally dependent on the coal industry. The town was developed to service the new coal mines in the area and it was anticipated at the time that additional mines and other industries might develop to share the tax burden. This has not occurred and the town continues to rely on the two existing mines to finance its operations. The other communities in the region; Chetwynd and Dawson Creek, existed prior to the development of coal in the area and thus had established sources of revenue although they do generate tax dollars from various industries servicing coal mines. The problems experienced by Quintette mine has impacted Tumbler Ridge in many ways, the most obvious of which are fewer residents in the community paying taxes. The numerous vacant houses compound this problem. Hopefully with Quintette under the operating management of Teck Corporation, increased stability will be brought to the region.

14.4.2 Provincial Taxes

Coal mines pay tax under the B.C. Mineral Tax Act, workers compensation, B. C. sales tax, B. C. fuel tax, B. C. water tax, import tariffs and motor vehicle licenses, etc. There is also B. C. income tax. In 1990 these taxes amounted to some \$63 million not including property taxes of \$18.5 million.

The previous coal royalty system was replaced, effective 1990, by the Mineral Tax Act. This new act was a result of negotiations between government and industry over the preceding two years. The industry was very appreciative of the effort the Provincial government made to provide a more equitable tax arrangement. The benefit of this effort resulted in a reduction of mineral taxes payable.

In addition to the taxes paid directly by the mining firms, coal shippers have also demonstrated a concern about the levels of property taxes being assessed on the railways and ocean terminals. Property taxes against national railways in British Columbia are assessed on a utility basis, much higher than for normal business properties.

In Canada various provincial governments impose a provincial fuel tax varying from 0 to 15

cents a litre. This tax on diesel fuel affects the cost of transporting coal on the railways. Diesel fuel taxes can be 7 to 8.5 times higher in Canada than in the U.S.A. The significant difference is what concerns the coal shippers in Canada inasmuch as we compete with United States coal producers in many of the same markets. These taxes not only increase costs of coal destined for offshore markets, but seriously inhibits Canadian coal from competing in the eastern Canada and United States markets against the U.S. supplies. In 1990 these fuel taxes increased rail transportation costs by approximately \$26 million.

The coal industry in British Columbia has attained an impressive safety record. Laudable as this is, it has resulted in an overpayment to Workers Compensation Fund of \$14 million.

A process is under way to rebate this overpayment through reducing future premiums. The coal producers each considered that during these times of scarce investment capital and to assist in maintaining competitiveness, the province should refund the overpayment in its entirety now.

14.4.3 Federal Taxes

Federal government taxes include income tax, payroll taxes sales taxes, import tariffs and excise taxes on fuel. On January 1, 1991 sales and excise taxes were replaced by the 7 per cent Goods and Services Tax. On a national basis, the coal producers are concerned about the burgeoning national debt which could lead to increased tax levels.

14.5 Government Policy

Reference was made in Chapter 10 to the impact, on the coal industry, of the federal government's policy of maintaining a high interest.

This policy has a much larger impact on a Canadian coal producer's ability to compete on the international market than any of the foregoing factors. Most of the coal trade is based in United States dollars. A producer can be fully competitive in the market place, but could see his profitability reduced significantly when he loses on exchange rates. The Bank of Canada's policy of maintaining the differentials between Canadian and the U.S. interest rates is particularly damaging to export businesses. For each five cents the Canadian dollar strengthens against the U.S. dollar, the Canadian industry loses \$37 million in sales revenue. Two

competing countries selling coal at approximately the same price in U.S. dollars will have significantly different net backs in terms of their own currency. (Figure 10.5)

For example, if coal was selling for \$50 U.S.A. a tonne, and the Canada/U.S. exchange rate was 0.85, Australia/U.S. was 0.78 and South Africa/U.S. was 0.38, then in their own currencies:

- Canada would receive \$57.50/tonne in Canadian dollars
- Australia would receive \$61.00/tonne in Australian dollars
- South Africa would receive \$81.00/tonne in South African rand

The British Columbia coal producers have been able to remain competitive to date in most cases. Those who were losing their competitive edge have either sold their properties at less than the invested capital or have restructured their finances and operations. Other producers, as a result of market forces, have had their margins reduced.

Much has been written about the Northeast coal development and there has been considerable criticism of the resource development policy applied at the time. Recognition should be made of the fact that developers, customers and government were all involved in the project and all must share in the results of the undertaking; they each have obligations to do their best to make it more successful. Further criticism will not help; however, a recognition of errors is important to avoid repeating mistakes in the future. One of the fundamental errors was to allow commercial desires to over-ride technical/economic soundness.

The fact remains that considerable funds were invested in mine development and infrastructure and that these facilities are still in place today. Therefore it is vital that the new operators of Quintette be given the opportunity to keep the development alive. If not the communities including Tumbler Ridge, Chetwynd, Dawson Creek, Prince George and Prince Rupert will all suffer along with the general public, the investors, government and the customers. The government must; however, be cautious about further direct investment in the development while taking actions as necessary to facilitate the success of any sound restructuring plan for northeast coal.

Returning to the overall aspect of the provincial coal industry's ability to compete in the longer term increased competition is anticipated. Even though prices are expected to increase, costs will also be rising. Japan, being one of the largest purchasers of seaborne coal, will use the new production from Indonesia to keep Australian coal prices as low as possible. Although it will be Australian coal that will tend to set prices, Canada's competition both in Asia and Europe will be with the United States.

Should the new deep sea coal terminal currently being proposed for the port of Los Angeles be constructed, the British Columbia coal producers will face even greater competition.

Every component of the coal producers costs in the province is going to have to be examined. Canada's ability to compete cannot be taken for granted and every link in the coal chain from mine to customer will be under pressure to improve productivity and reduce costs. If this does not happen, market opportunities will be lost and all will lose out.

Early in this discussing on competitiveness, it was pointed out that the ability to compete is a function of costs and selling price. The mines in British Columbia are developed on the basis of projected coal demand at certain price levels. Most of this capacity was put in place to satisfy the Japanese market. Japanese purchasers were very thorough in evaluating the competitiveness of each mine prior to entering into purchase agreements. Both the government and industry invested large sums of money on the basis of long term relationships. Japan is currently setting the price for coal, and when prices are forced to such low levels that adequate returns are not made on these investments, it is difficult for governments to justify to the general public, the expenditure of such funds. More and more frequently the public is questioning the manner in which Japan is perceived to be conducting its international business. Prices must be such to ensure the supplying country of raw materials is adequately compensated for the use of a non-renewable resource and also to pay full costs of environmental protection. Failing this, increased pressure will be placed on the provincial and federal governments to take mitigative action.

15. GOVERNMENT'S ROLE IN INTERNATIONAL TRADE PROMOTION

With the changes that are taking place in world coal markets there is a greater role for government to play in international promotion of the province's coal resources.

Areas in which the government of British Columbia can assist fall into two broad categories:

- Education
- Support to the industry

15.1 Education

Education involves making people more aware of the role coal plays in our society today and the enormous potential it has for the future. There are many misconceptions about the production and use of coal and these will have to be corrected. Every opportunity must be taken to educate the public on the use of coal, to ensure the potential is recognized and to demonstrate that British Columbia is a good, reliable source of coal for the world.

One of the better ways to accomplish this is through trade promotion exhibits.

These exhibits can vary from large expensive visual displays staffed by persons knowledgeable about the industry to more modest displays with hand-out material.

Every opportunity should be taken when the province is planning international trade promotions to include a section on coal. These exhibits should attempt to cover the whole story on coal in simple terms from environment, what coal does, how it is utilized through to demonstrating Canada's technology and our ability to supply coal. To accomplish this requires a good information base to ensure current data is available about the industry:

- A knowledge of the types and quality of various coals and products available from the province.

- The types of coal expertise available in Canada and how this expertise can be utilized.
- Information of the type of coal research and development taking place in the province.
- A knowledge of the province's coal resources and of the companies operating in the province.
- Ensure the federal government's trade commissioners are current with respect to the province's coal industry.
- Equally important is to ensure provincial ministers and government staff have been fully briefed on the coal industry including government policies with respect to coal.

It is important to be selective as to which countries Canadian coal is promoted; however, the opportunity to have coal included in any provincial international trade promotion should not be missed.

15.2 Support to the Industry

One of the attributes of the Canadian coal industry is that it has a highly qualified and effective marketing force.

The support of the provincial government to this marketing force has benefit. This is not to suggest that the province get involved in contract negotiations with the customer, far from it. Companies are quite able and should conduct these negotiations on their own. However, a senior government official confirming support and describing specific policies can at the right time be very helpful.

The opportunity to participate in technology exchange should be explored in conjunction with the Government of Canada. There are many windows of opportunity in coal research and

development for the exchange of information and financial participation in specific projects.

There have been times when specific coal missions have proved to be worthwhile. These joint industry/government missions, in addition to primary objective, often have side benefits as well.

The industry should be made aware of trade promotion plans and provided there is sufficient advance notice can assist in the development and execution where appropriate.

Well organized and executed trade promotions can be very effective in developing a country's trade. They must; however, have well defined objectives and be directed to an audience that has decision making capabilities.

Bi-lateral trade agreements may become more important to the coal industry as the nations

of the world place increasing emphasis on environmental protection and increased requirements for electricity take place in the developing world. Canada is advancing in terms of new technology for electric power generation coupled with environmental protection. There is evidence in Eastern Europe that enquiries are being made for environmental experience to assist in addressing coal related concerns. The provincial government has expertise in these areas and should be able to provide assistance. One specific area that comes to mind is the government's expertise and experience with the coal development review process and the ongoing monitoring.

The provincial government should be alert to these opportunities for both the service sector and the province's coal industry experience.

16. ENVIRONMENTAL CONSIDERATIONS, CLEAN COAL TECHNOLOGY AND DOMESTIC ENERGY POLICY

16.1 Environmental Considerations and Clean Coal Technology

The closing decade of the twentieth century holds the potential for major conflict between the drive for resource development and the need for environmental protection. Such conflict is not required; it accomplishes nothing and seldom, if ever, leads to reasonable solution. Furthermore, resource development and the exercising of environmental responsibility are not necessarily incompatible goals.

Global consciousness about the environment, at least in the developed world, has risen dramatically. Individuals and organizations throughout the world have been working to find practical means of initiating what the 1987 Brundtland Commission targeted as "sustainable development".

Sustainable development is described in general as an activity in which the environment is fully incorporated into the economic decision-making process as a forethought, not an afterthought. It holds that resources must be treated on the basis of their future, as well as their present, value. This approach offers genuine hope of economic development without environmental decline.

The well-being of citizens is dependent on the health of both the environment and the economy. A threat to either will imperil the way of life to which we have become accustomed. We must meet our environmental goals in ways that promote economic prosperity. Business needs clear rules dealing with the use of environmental resources, and these must be applied fairly and consistently.

The federal government responded to these concerns with the introduction of "Canada's Green Plan", a comprehensive document outlining the country's objectives in achieving sustainable development. This was followed by the introduc-

tion of Bill C-13, an act to establish a federal environmental review process.

British Columbia responded by establishing the "British Columbia Round Table on the Environment and the Economy". This panel is currently in the process of conducting hearings throughout the province to ensure the views of the public are taken into account in recommending any course of action. A number of theme papers were produced in preparation for the hearings including one on "Sustainable Development and Energy".

At about the same time the Ministry of Energy, Mines and Petroleum Resources published the British Columbia Energy Policy "New Directions for the 1990s".

These are all laudable actions responding to a genuine concern. Important as the cause may be, it is also of the utmost importance to adopt a balanced view in developing government policy. Experience has shown that in dealing with environmental issues, emotion often takes over from common sense. In addressing each issue it will become increasingly important to put emotion aside and deal with each item on a factual, well reasoned basis, taking all factors into consideration.

The issue of environment is not new to the coal industry. The industry was dealing with environmental matters before the current concerns became paramount. The initial focus was an environmental protection and the reclamation of disturbed land in the mining process. Mining companies have proven that lands disturbed in the mining process can be reclaimed. These reclamation programs include slope stability, revegetation and, where practical, wild life habitat. All companies include an environment and reclamation department in their corporate structure. Environment and reclamation have become standard operating procedures; however, research is continuing and monitoring programs are on-going.

Few persons are aware how much coal is used in Canada for the generation of electricity. The use of coal for power generation is subjected to strict environmental standards with respect to gaseous and solid emissions. Canada's standards are among the highest in the world in terms of performance. Canada is fortunate to have a resource of low sulphur coal; therefore we do not face the problems experienced by other countries. Nevertheless, the industry has always responded to changing emission requirements and has taken a pro-active role in developing technologies which can more than meet existing standards.

In recent years, the world has become increasingly aware that a growing population, demanding increased standards of living and accelerating development are influencing global climate. A debate is occurring within the scientific community with respect to global warming and related climate change. It is expected that this debate will go on for some time before absolute proof of the phenomena is obtained.

Scientists in general are in agreement that climate change could occur and the possibility of serious consequences exists. Even though there are still many scientific and socio-economic uncertainties as to the extent and pace of change, it is prudent to take action on possible mitigating measures while the scientific process runs its course.

There are costs associated with taking early action and these costs will ultimately be borne by the general public. Therefore it is important to recognize these costs when developing policy.

In global terms, Canada is not a major contributor to climate change. No more than two per cent of the world's CO₂, two per cent of nitrous oxide, one per cent of methane and two per cent of the CFCs are produced in Canada. The nation cannot deal with climate change in isolation from the rest of the world. For good reason, Canada is an energy intensive nation. We have because of this developed technical skills in dealing with energy matters. These same skills can be used to address the concerns of global warming and transferred to other countries around the world.

Due to the chemical composition of hydrocarbons, they have been identified as one of

the major contributors to global warming. And of all the hydrocarbons, coal has been cited as the largest single contributor of radiative gas emissions. While further analyses proved this to be incorrect, particularly in Canada, coal is still living with images of the past and suffers from an enormous credibility gap. Burned without using current technology, coal could justifiably generate this concern. However, technology is available today to utilize coal cleanly and this technology is being advanced to improve even more the capabilities of using coal in an environmentally acceptable manner.

These technologies were discussed in some detail in Chapter 12.2, "Technological Factors Likely to Affect Coal Usage". This section described in some detail the clean coal technologies available today. These will not be repeated here. The discussion does confirm, however, that technology is available to utilize coal in a safe, clean efficient manner and that coal can also contribute to alleviating the concerns over global warming.

The incremental costs associated with advancing new technology in the early stages can be justified when the need to take action is identified. The public and government have identified the concern, industry stands ready to respond.

The Canadian coal industry committed itself to a program of:

- promoting conservation and the wise use of energy
- improved efficiency in coal production and electricity generation
- the development of improved scientific knowledge
- a cooperative, consultative approach to meeting the country's energy challenges

Whatever steps are taken to ensure environmentally compatible sustainable environment, the financial, social, political and economic costs must be measured against the country's existing debt and tax load. A strong economy is essential to a healthy environment.

Actions that weaken the economy and render it uncompetitive internationally, leave the province and the country poorly equipped to address new environmental challenges.

16.2 Domestic Energy Policy

British Columbia is fortunate in being blessed with a variety of energy sources sufficient to meet not only its own requirements, but to supply energy to markets outside the province as well. The document, *British Columbia Energy Policy: New Directions for the 1990s*, identifies four foundations for the provincial energy platform:

- efficient energy
- clean energy
- secure energy
- energy for the economy

The province's primary energy resources include hydro power, natural gas, oil and coal. In the past energy requirements have been satisfied with hydro, natural gas and oil. There exists today, however, a fourth option, that being coal fired electric power generation. This option has been examined from time to time in the past. Changing circumstances justify a fresh look at coal fired generation within the province.

At first glance coal fired power generation appears to be a quixotic proposal given the concerns of the general public over atmospheric quality. These concerns are based on a lack of knowledge and when facts are presented, can be alleviated.

A vital component of any sound energy policy is a diversity of options. Previous sections of this report have demonstrated that coal can be utilized in an environmentally acceptable manner. The province's coal industry is going through a period of instability and it has been demonstrated that a weakness of the province's coal industry is that it is entirely dependent on sales outside the province.

In order to create stability within the industry, it is desirable to develop a domestic market for coal. There is no suggestion that a coal fired power plant be constructed to replace existing hydro generation, quite the contrary. The need for increased electrical demand would have to be demonstrated. That demand may not be required for some time into the future; however, including the approval process, power projects require a long lead time and coal should be considered as a serious option.

There are a number of benefits to such a plan beside the obvious benefit to the coal industry. Some of these are:

- It would expand the province's energy base.
- It creates a new industrial base in the province.
- It develops new technology that can be transferred to developing countries.
- It would complement the hydro system.
- It would meet environmental standards.
- It could assist in the development of offshore coal sales through bi-lateral trade arrangements.
- It would provide increased stability to the provincial coal industry.
- A project of this type should not be sold on the basis of creating jobs, as jobs will be involved in any type of power development. However, coal fired plants create more jobs than hydro plants, because mines must be developed to provide the coal. These are permanent jobs with long term security.

Any such development should only be taken on an economic basis. The province has a choice of coals to supply an on site plant, technology is available and the coal is available.

It is therefore recommended that the province commission B.C. Hydro to undertake a feasibility study on the use of coal fired electric power generation within the province using latest available technology such as integrated gasified combined cycle power generation.

In accordance with the initiatives set forth in the *British Columbia Energy Policy*, two firms submitted applications to develop small coal fired power plants in the Elk Valley Region. All local communities strongly support a power plant in this area. They view such a development offering diversification to the industrial base and providing increased stability to the local economy. The applications are currently under review and are subject to an environmental assessment to ensure the required emission standards are met.

17. GOVERNMENT FISCAL AND REGULATORY IMPACTS ON INDUSTRY

17.1 Government Fiscal Policies

Government fiscal policy at both the federal and provincial levels directly impacts an industry's ability to raise financing, invest funds, earn a profit and influences the ability to compete.

Taxes in society are often referred to as a necessary evil if a country is going to supply the basic services society demands. The concern, of course, is that the level of taxation is equitable. In the case of industry it is vital that the levels of total government take do not reach such heights to deter the ability to generate profit and create wealth for the country as a whole.

Fiscal policies then, are continuously watched by industry in order to identify impacts. It is for these reasons that there is an almost constant dialogue between industry and government on the matter of fiscal policy and taxation.

Currently the federal government's policy of maintaining interest rates at high levels to ward off inflation and attract capital, has the effect of maintaining the Canadian dollar at artificially high levels compared to the United States dollar. This high exchange rate reduces the income for all export industries most of which conduct their trade in United States dollars. The impact of this policy on the Canadian coal industry has been demonstrated in this report. Likewise the effect of excise taxes, high property and resource taxes have all been discussed in light of provinces' coal industry being able to maintain its competitive position in world coal trade.

Governments are urged to listen to the concerns of industry and review data presented in support of industry's position. It is vitally important to maintain a dialogue with each other on these important issues. Only through all levels of government working together with industry can a better appreciation of one another's requirements be understood.

The government of British Columbia recognized an inequity to the coal industry in the manner mineral land taxes and royalties were being assessed compared to other resources in the province. After careful examination a new Mineral Tax Act was proclaimed. Unfortunately most of the saving resulting from this action was offset in the other areas such as higher unemployment insurance rates. Nevertheless the industry appreciates such initiatives. The fact remains, however, that when all the taxes are added together it becomes increasingly difficult to maintain a competitive edge. Canada as a whole is going to have to look at the combination of federal-provincial policies in light of international trade in an ever increasingly competitive world.

The various fiscal policies and taxes impacting the coal industry have been identified elsewhere in this study. One aspect that bears repeating is that of subsidies. The coal producers are opposed to direct subsidies on production. It is their opinion that if various countries around the world were to cease subsidizing uneconomic coal production, then the world coal market would establish realistic and equitable pricing regimes. In other words, let the free market prevail.

The provincial and federal governments are urged to persist in the GATT negotiations and other mechanisms for the removal of subsidies on coal production, particularly in Europe.

One area that continues to be sensitive within the coal industry is the investment made by the province to provide infrastructure in the development of new coal regions in the province. When this subject arose it was more in the context of the investment being made for one industry rather than for a mix of industries.

There has been considerable debate on this subject over the years which has probably led to the position articulated by most coal producers that is: government should not invest heavily in provid-

ing infrastructure for one company or one industry. Such investments should only be made when the benefits are shared by a mix of commercial enterprises and when there exists a reasonable assurance that such investment will have a net payback to the province.

A number of companies stated that because mining is a cyclic enterprise, that government fiscal policy should include provisions to enable various types of tax relief when companies are struggling to survive in difficult times. There would naturally have to be some assurance that the company could be viable in the future.

On the subject of fiscal policy as it relates to the coal industry, one view expressed on a number of occasions was that although it was important to keep taxes equitable, too much relief is not practical because of the way coal pricing is dominated by Japan, if special tax relief programs are implemented by government in order to maintain trade, the prices will only be lowered to reflect the new cost regime and the company and province will both lose revenue, the only winner being the customer.

17.2 Impacts of Government Regulatory Policy

The federal and provincial government attitude in Canada has always been supportive of the coal trade. There has not been any intentional artificial constraints placed in the path of such trade. In fact, in the past government has invested heavily in providing basic infrastructure for resource industries and coal has been a beneficiary of some of this investment. The fact that Canada has established itself as a reliable supplier of coal rests in part with the support of government policy.

Generally speaking, the coal producers consider the regulatory framework within which they operate in the province, reasonable. Each though was quick to point out that there were some concerns, some more serious than others.

From the inspection standpoint, mention was made of the recent policy of charging for mine inspections. It was viewed as another cost to be incurred when every effort is being made to reduce costs. Some mines expressed the opinion that the new safety code was being used by the unions as a negotiating tool which is detracting from the intent which is to promote safety.

The most frequent concern voiced was in relation to the establishment of environmental policy and jurisdictional control.

The court ruling on the Alameda-Rafferty dam in Saskatchewan has thrown the whole environmental review process into disruption. The net result of this has been a jurisdictional dispute between the federal government and the provinces. Prior to these events the federal and provincial departments of environment had a good working relationship and the approvals although slow, proceeded in an orderly fashion. At this time any activity that requires an environmental approval needs separate environmental assessments, one for the province and one for the federal government. Even routine changes to operating procedures has now become a complex process both time consuming and expensive.

One result of this jurisdictional dispute is that both levels of government are competing to set a higher standard in order that they will not find themselves in an "embarrassing position". However, they fail to recognize the implications of such action on industry.

This action leads to costly delays in obtaining approvals and impacts directly on operating costs. When the Green Plan was announced, the federal government assured industry that the additional costs of meeting emission standards would not affect Canada's international competitiveness because all developed countries would be taking the same action. Although this may be true, there has not been any evidence to date that would support such claims, particularly in the developing countries. But what does directly affect our competitiveness, which is already under strain, are jurisdictional disputes of this nature. Should a company be forced to spend large amounts of money unnecessarily to satisfy one jurisdiction over another makes no economic sense and does not resolve anything. The only alternative a company may have open to it, is to satisfy one jurisdiction and face potential prosecution and fines from the other.

Both governments are strongly urged to resolve these differences.

On a provincial basis, in addition to the jurisdictional dispute, the Department of Environment appears to be experiencing some growing

pains. Concern was expressed that there has to be better communication between field staff and head office in Victoria. There does not appear to be a common approach within the Ministry of Environment for reviewing projects.

There was also an expression of concern that the Mineral Development Review Process did not seem to be quite as effective as it has been in

the past. This was probably due to environmental considerations changing so quickly. Energy Mines and Petroleum Resources recognized this latter problem and have updated the MDR process including the introduction of the "Mine Development Assessment Act" in July 1990. A description of the Mine Development Assessment Process is included in Appendix "D" of Volume II.

18. FACTORS AFFECTING TRANSPORTATION OF COAL TO MARKET

British Columbia has a good infrastructure system in place to service its coal industry. Two railway systems bring coal into the Vancouver area where two deep seaports, Westshore Terminals and Neptune Terminals provide ship loading facilities. In the central part of the province, B. C. Rail and C.N. Rail provide service in series to the Ridley Island bulk terminal at Prince Rupert.

These facilities are state-of-the-art. Ridley Island and Westshore terminals can handle the largest ships in service today and Neptune loaded up to 150 thousand tonne coal carriers. The railways and terminals are highly efficient and contribute to the province's reputation as a reliable supplier.

Obviously the terminals and railways are concerned about the current state of the coal industry in the province. They have cooperated with the mines in cost reduction programs. They also realize that if the mines cannot remain com-

petitive they too will suffer financial losses. Also like the mines they are very conscious of the tax levels and facility charges by the government.

The railways and terminals have made significant contributions to the Canadian coal industry while at the same time they are a recipient of the benefits of a healthy coal industry.

The provincial network of railways and terminals assures customers of a reliable delivery system. If for any reason one system is disrupted due to unforeseen circumstances such as floods or avalanches, the coal can be re-routed through another facility.

The ability to maintain a continuous transportation flow is an important component of the province's coal industry and partially offsets the longer rail hauls required compared to competing sources of supply. This is yet another plus that Canada offers in terms of security of supply.

19. CONCLUSIONS

Overall demand for coal in the world continues to increase. This demand is also reflected in the internationally traded coal. Sufficient production capacity exists to meet the demand for both metallurgical and thermal coal through to 1995 when additional thermal coal capacity will start to be required.

Demand for metallurgical coal remains relatively flat; moreover, as new technologies allow the use of lower quality and less expensive coal, the demand for British Columbia's hard coking coal will decrease.

World requirements for electricity are growing at a rapid rate, with much of this electric power to be generated from coal. By 2010 it is possible there will be a three fold increase in thermal coal supply requirement.

Of the total coal produced in British Columbia, virtually all of it is consumed outside the province and 95.5 per cent outside Canada. Of this 91 per cent was metallurgical coal and 8.0 per cent was thermal coal. As a result of changing market demands the metallurgical trade will become increasingly competitive and provincial producers must carefully examine increased participation in the thermal coal market. This dependence on the international market leaves the province in a vulnerable position and it should therefore examine the potential of developing a domestic coal requirement by means of coal fired electrical generation and other value added technologies.

Although, in the minds of the general public, concern about the use of coal persists, these fears can be alleviated. Current new clean coal technologies place coal in the category of a safe, reliable fuel.

Coal is an important component of the province's economy as evidenced by the fact that it is:

- B.C.'s most important mineral commodity;
- \$1.6 billion in gross industry revenue
- \$1.0 billion in production value
- \$283 million of goods and services purchased in the province
- \$77 million in taxes to the province
- 5600 employees
- Four communities rely directly on the coal industry; several more are heavily dependent on the industry

In spite of the growing demand for coal, the producers in British Columbia are not achieving adequate returns on the capital invested. Circumstances and causes that lead to this situation include:

- A coal price that is too low to enable adequate returns on capital invested.
- Canada's monetary policy of maintaining high interest rates resulting in an unfavourable exchange rate for coal exported in U.S. dollars.
- An oversupply situation with installed production capacity in excess of current world demand.
- The forecast demand for coal has not grown at the rate or by the volume predicted.
- Japanese domination of the world seaborne coal trade resulting in their becoming price setters.
- Increased levels of taxation at the municipal, provincial and federal levels.
- Increasing labour costs.
- Fuel taxes on rail transportation of coal.
- Production subsidies and other direct government assistance provided on coal production in the EEC and Japan.

In addition the following factors are threatening the industry's ability to remain economically competitive:

- 40 per cent of gross revenues go toward transportation costs.
- Annual rail costs are \$500 million.
- Port costs are \$100 million.
- The coal industry's total tax bill was \$84.1 million in 1990.
 - \$47.7 million was from fixed sales and property taxes.
 - Property taxes represent \$18.5 million or 39 per cent of those fixed taxes.
- Total employee remuneration per tonne produced increased 8.3 per cent in 1990.
- Federal environmental assessment review guidelines are adversely affecting industry.

There is just cause to have serious concerns about the provincial coal industry:

- The Byron Creek mine is for sale.
- The Line Creek mine was recently sold for less than the invested capital.

- Quintette Coal has undergone a major restructuring.
- Westar, owner of the Balmer and Greenhills mines, is experiencing severe financial hardship.
- These five mines represent almost 70 per cent of production.
- Operating margins before taxes have been cut in half over the past three years.
- Return on capital employed has been poor, ranging from 1.0 to 2.5 per cent.

There is little doubt that coal will continue to play an important role in British Columbia, but the character of the industry is certain to change. There is no guarantee that some closures may not occur in the industry.

The industry itself is working hard to maintain profitability and structure itself for the future. While the industry is opposed to subsidies, there are actions the government can and should consider taking to assist the industry. These actions are identified in recommendations contained in Chapter 20.

20. RECOMMENDATIONS

This study has identified a number of problems facing the coal industry in the province and has also identified areas of potential opportunity.

To ensure the coal industry's contribution to the province's economic, social and environmental goals can be recognized and enhanced consistent with maintaining the domestic and international competitiveness of the industry it is proposed that the government initiate appropriate action to develop a strategy for coal in British Columbia.

In developing such a strategy it is important to utilize the consultative approach which will involve further dialogue with those who have a vested interest in the industry. This would include the producers, the communities, the workers, and the service sector. It will also be advisable to keep the general public informed throughout the process.

There are specific actions items arising from the study which should be incorporated into the strategy. Some of these items require immediate attention. Therefore the government is urged to adopt the following course of action:

Recommendation:

Immediately initiate the development of a coal strategy for British Columbia.

Recognizing that the public is not well informed on the value of the coal industry to the province and that through the use of current and new technologies, coal can be produced and utilized in an environmentally acceptable manner, industry must work to dispel the current image of coal. However, this cannot be done by industry alone.

Recommendation:

- Publicly acknowledge the important role coal assumes in the provincial economy.
- Undertake a program to educate the public on the facts with respect to using coal which would illustrate coal, by utilizing current new technologies, can be used safely and cleanly without causing irreparable damage to the environment.

British Columbia is overly dependent on the export market for coal and thus leaves itself fully exposed to the cyclic nature and intense competition of the international marketplace.

Recommendation:

- Evaluate the opportunity to create a domestic market for coal within the province by complementing the existing hydroelectric generating capacity with coal fired thermal generating plants.
- In the short term, expedite the review process with respect to proposed small thermal generating plants in southeast British Columbia.

While waiting for provincial electrical demand to grow to such levels that will justify additional generation capacity, continue to monitor IGCC development.

Recommendation:

- Consider participation in some manner in any out-of-province demonstration plant that may be constructed. Such activity will reduce financial exposure and offer the opportunity to gain technical and operating experience with B. C. coals.

The coal industry in the province is suffering from the purchasing policies of the Japanese.

Recommendation:

- Deliver a strong message to the Japanese steel industry, in turn Japan, concerning the impacts of their present pricing policies.

The government of Canada's policy of maintaining a high Canadian dollar along with high interest rates has slowed inflation at the expense of the export industries and has been particularly harsh on the coal industry.

Recommendation:

- Renew provincial efforts to address federal monetary policies.

Direct subsidies to coal producers in competing coal supplying countries has resulted in unfair competition.

Recommendation:

- Bring increased pressure through GATT on EEC and other countries to eliminate the practice of coal subsidies.

The levels of taxation imposed upon the coal industry is of serious concern and impacts on the industry's ability to remain competitive.

Recommendation:

- Create an inter-ministry team to review the tax burden on the coal industry, including railways and coal terminals, and specifically examine:
 - Harmonize provincial/federal sales taxes.
 - Property tax.
 - Mineral tax.
 - Examine the discrepancy between coal vs. the metals royalty.

The delay in obtaining environmental approvals is costly to the industry in that it prevents timely action.

Recommendation:

- Take prompt action to resolve the jurisdictional dispute between the federal and provincial departments of environment to alleviate duplication of effort, unwarranted additional expense and costly delays.

British Columbia's potential to become a major supplier of coal has not been fully assessed.

Recommendation:

- Recognizing the growth in world demand for thermal coal, develop a program through the provincial Geological Survey Branch to define the potential of the British Columbia coal resources as a source of thermal coal.

With respect to property taxes, particularly in the southeast, there is a requirement for increased cooperation between the mines and local communities.

Recommendation:

- Develop a mechanism whereby the southeast coal communities are better informed of one another's capital programs and accept the offer from industry to discuss the impact of such programs prior to approval.
- Through the Department of Municipal Affairs, monitor the southeast coal communities' Industrial Tax Sharing Agreement more closely to ensure equitable treatment for all communities.

The industry has achieved an enviable safety record which has resulted in an overpayment to the Workmen's Compensation fund. The Board acknowledges this overpayment; however, its policy of repayment over time is not helping the industry, whose cash flow problems are current.

Recommendation:

- Examine immediate rebate of all outstanding Workers' Compensation Fund overpayments.

Well organized and executed trade promotions can be very effective in developing trade through informed presentations.

Recommendation:

- In cooperation with industry, ensure provincial representatives abroad and formal trade missions have current and factual information on the coal industry. Where possible industry should be invited to participate in trade missions.

Government can also assist industry through bi-lateral trade agreements.

Recommendation:

- Investigate bi-lateral agreements that may present the opportunity to use provincial coal mining and environmental expertise abroad.

The continued use of coal in the longer term will be influenced by the demand to minimize environmental impact.

Recommendation:

- Monitor clean coal technology development and support coal research and development where and when appropriate.

A potential opportunity has been identified for B.C. to supply coke to the U.S. midwest.

Recommendation:

- Undertake an investigation of the economic potential of establishing a coke plant in the province. Coal companies should be invited to participate in the study.

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**COAL IN BRITISH COLUMBIA
AN ASSESSMENT OF FUTURE PROSPECTS
APPENDICES**

NOVEMBER 1991

**RICHARD T. MARSHALL
RESOURCE MANAGEMENT SERVICES**

APPENDICES

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Appendix B: The Impact Of Clean Coal Technologies On The Use Of Thermal Coal For Electric Power Generation

Appendix C: The Coalfields of British Columbia

Appendix D: British Columbia's Mine Development Assessment Process

Appendix E: Glossary of Terms and Abbreviations

Appendix F: Coal Companies Interviewed

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APPENDIX A.

Appendix A

**IMPACT OF CHANGING COKEMAKING
AND IRONMAKING TECHNOLOGY
ON COKING COAL DEMAND**

FOR

**MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES
GOVERNMENT OF BRITISH COLUMBIA**

BY

H.N. HALVORSON CONSULTANTS LTD.

July, 1991

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1 INTRODUCTION

In May, 1991, the Ministry of Energy, Mines and Petroleum Resources awarded a contract to H.N. Halvorson Consultants Ltd. to assess how changing cokemaking and steelmaking technologies could affect coking coal demand.

The Japanese steel industry has often stated its intentions towards the adoption of new technology. The focus of the study was, therefore, directed at soliciting the opinions of North American steel experts on the possibility of the Japanese realizing their plans.

A field trip was undertaken to interview steel producers, industry consultants and government experts on steel and cokemaking. Organizations in Ottawa, Toronto, Washington, Pittsburgh and Charlotte, North Carolina, were interviewed. In addition, coal industry people were visited in Vancouver and interviewed by telephone in Australia and Alberta. The people and organizations contacted are listed in Table 1.1.

The opinions, forecasts and data solicited from the interviews were combined with published and in-house information to generate the forecasts contained in this study.

While the forecasts in some cases are quite crude, it is believed they are of sufficient accuracy to indicate trends. The timing and actual impact of each technological change on coking coal must be taken as approximate.

During the course of the study it was learned that two studies germane to the subject had been recently completed. A consortium of Canadian and Australian coal producers had commissioned CRU Limited of the U.K. to forecast the impact of PCI (pulverized coal injection) on coking coal. While this study was not provided, its broad forecasts were.

The Ministry of Energy, Mines and Resources, Canadian Carbonization Research Association, Canadian Steel Industry Research Association and eight Canadian companies commissioned Stelco Technical Services Limited to assess new steelmaking technology. The report (Strategic Study of Future Ironmaking Processes, 2 volumes), issued September, 1990, was made available to this present study and proved very useful.

Table 1.1
Organizations Interviewed

Organization	Person	Title	Address	Telephone
Algoma Steel	Dr.T. Burgan	Manager Coke Making; Chm. Canadian Steel Industries Research Association	Sault Ste. Marie, Ontario, P6A 5P2	(705)945-2600
American Iron Carbide Corp.	D. Keady	President	180 N La Salle St., Chicago, Illinois, 60601	(312)726-2618
American Coke and Coal Chemicals Institute	D.C. Ailor	Director of Regulatory Affairs	1255 - 23 St., N.W. Washington, D.C. 20037	(202)-452-1140
American Iron and Steel Institute	Dr. W. Dennis	Vice President, Manufacturing and Technology	1133 - 15 St., N.W. Washington, D.C.	(202)452-7111
BHP-Utah Coal Ltd.	Dr.G.D. Lill	Manager, Marketing	167 Eagle St., Brisbane, Queensland, Australia, 4000	(07)226-0600
Canadian Government				
a) Energy, Mines Mines and Resources	T.R. McInnis	Commodity Specialist, Coal and Iron Division	605-460 O'Conner St. Ottawa, Ontario	(613)995-1118
b) CANMET	M.C. Campbell	Manager, Extractive Metallurgy Laboratory	259-555 Booth St. Ottawa, Ontario, K1A OG1	(613)996-2929
	Dr. J.F. Gransden	Research Scientist Combustion and Carbonization	Regional Road 36, Bells Corners, Ontario	(613)996-8734
Dofasco Inc.	D.N. Eastman	Senior Manager, Commercial Research	Box 2460, Hamilton, Ontario, L8N 3J5	(416)544-3761
	B.A. Strathdee	Assistant Director of Research, Primary Processes		(416)548-4708
	D.H. Pomeroy	Senior Research Engineer		(416)548-4748
	R.A. Kammermayer	Research Assistant Supervisor Cokemaking		(416)548-4723
Gas Research Institute	S. Freeman		Chicago	(312)399-8100
Hatch Associates Ltd.	R.P. Smith	Associate	2800 Speakman Dr.,	(416)855-7600
	J.A.T. Jones	Process Engineer	Mississauga, Ontario,	
	J.H. Cox	Process Engineer	L5K 2R7	
IEA Coal Research	E.D. Jamieson	Head of Supply, Transport and Markets	10-18 Putney Hill, London, SW15, 6AA, England	081-780-2111
			5040 Bear Lane, West Vancouver, B.C. V7W 1L1	(604)922-0761
Manalta Coal Ltd.	R.H. Kilburn	Manager, Corporate Planning and Marketing	734 - 7th Ave., S.W. Calgary, Alberta, T2P 3P8	(403)294-5570
Midrex Corp.	G.S. Branning	Marketing Services Specialist	2400 Charlotte Place,	(704)373-1600
	J. Kopfle	Manager Marketing Services	Charlotte, North Carolina, 28244	

Table 1.1
Organizations Interviewed - (Cont'd.)

Organization	Person	Title	Address	Telephone
National Coal Association	C.D. Holmes	Vice President	1130 - 17th St., N.W. Washington, D.C., 20036	(202)463-2654
National Steel Co.	J.A. Rainis K.P. Hass	Chief Economist Manager, Products/Process	20 Stanwix St., Pittsburgh, PA, 15222	(412)394-4688 (412)394-4121
Nucor Corp.	F.H. Iverson	Chairman, Chief Executive Officer	4425 Randolph Road, Charlotte, North Carolina, 28211	(704)366-7000
Ontario Hydro	J.D. Drysdale	Senior Fuel Specialist, Fuels Division	700 University Avenue, Toronto, Ontario, M5G 1X6	(416)592-8361
Steel Manufacturers Association	J. Collins	President	304-815 Connecticut Ave. Washington, D.C.	(202)331-7027
Stelco Ltd.	A.S. MacKenzie	General Manager, Raw Materials	Stelco Tower, Hamilton, Ontario, L8N 3T1	(416)528-2511
Sun Coal Co.	J.J. Knoerzer	Senior Coal Technologist	4711 Old Kingston Pike, Knoxville, Tennessee, 37939-0388	(615)558-3265
U.S. Government				
(a) Department of Energy Information Administration	Ms. L. Guey-Lee S. Sitzler	International Economist Coal Division Chief, Coal Data Analysis and Forecasting	507-1707 H Street, N.W. Washington, D.C. 20585	(202)254-5470 (202)254-5392
	F.M. Mayes	Coal Export Analysis		(202)254-5409
(b) U.S. Bureau of Mines	T. Peters R.E. Brown	Iron and Steel Specialist Iron and Steel Scrap Specialist	2401 E Street, N.W. Washington, D.C. 20241	(202)634-1022 (202)634-1752
University of British Columbia	Dr. K. Brimacombe	Prof. Metallurgy, Dept. of Metallurgy and Minerals Engineering	Vancouver, B.C. V6T 1Z4	(604)228-3667
Westar Mining Ltd.	J. Mathews	Market Research	1176 West Georgia St. Vancouver, B.C. V6E 4B9	(604)681-8222

2 EXECUTIVE SUMMARY AND CONCLUSIONS

2.1 GENERAL

The steel industry is actively exploring new steelmaking technology. This follows a period of approximately two decades of stagnation. Since the introduction in the 1960s and 1970s of basic oxygen steelmaking and scrap-based mini-steel mills (electric arc furnace), there has been little fundamental change in steelmaking technology. The underpinnings of the industry still remain the coke oven and the blast furnace. In the last few years a concerted effort has been launched to develop new technology that will divorce steel-making not only from coke but also from the blast furnace. In addition the development of thin dimension continuous casting has opened up the whole flat product market to mini-steel mills using scrap iron.

The driving force behind the move to coke-free steelmaking is twofold: (1) to reduce costs by substituting lower value coals for coking coals and (2) to alleviate the pollution problems inherent in cokemaking.

There seems little doubt that major changes are coming that will reduce and/or eventually eliminate the need for coking coals in steelmaking. The only uncertainty is the timing of the changes and hence the rate of decline of coking coal consumption.

Superimposed on this trend to new technology is the fact that steel production is expected to stagnate or even decline in developed nations but grow rapidly in the developing world. Because of capital constraints and smaller market sizes, the developing world will desire smaller sized production units requiring flexible equipment and technology.

2.2 THIN SHAPE CASTING

The U.S. mini-steel company, Nucor Corporation, has successfully commercialized the continuous casting of a 25 mm thick steel plate that can be

reduced on a cold mill to steel sheet. This has divorced sheet making from the intermediate step of hot rolling. Hot rolling mills are very expensive and require throughput rates in the 2-3 mtpy range. The inability of the mini-mills to justify hot rolling capacity has kept the large flat product market as the last preserve of the integrated steel companies.

Nucor Corp. has yet to prove its ability to produce high quality, cold rolled sheet. Success is fully expected by many in the industry. In addition, considerable effort is being spent worldwide on making near-net flat shapes (a few millimetres in thickness) that may make cold rolling unnecessary.

In the short term (to 1995), 3-5 mtpy of Nucor type capacity may be built in the U.S. Allowing for some BOF closures, this additional tonnage might increase total scrap based, electric furnace share of U.S. steel production to 45% from today's 39%. Some capacity is also expected in Italy and perhaps Spain. Also some electric furnace capacity will likely be built in the developing world.

After 1995, providing the production of quality sheet is perfected, considerable growth in electric furnace steel production is likely. This study forecasts that by 1995, 2000 and 2005, perhaps 37%, 50% and 52%, respectively, of total western world steel will be made with electric furnace facilities. This translates into approximately 20, 70 and 80 mtpy in 1995, 2000 and 2005, respectively, less coking coal being required than if the 1989 electric furnace share of 32% had prevailed. The corresponding reductions for Japan are 1, 2 and 2 mtpy less coking coal in 1995, 2000 and 2005, respectively.

2.3 COKEMAKING TECHNOLOGY

The Japanese steel industry has commercialized a number of cokemaking changes that have reduced the amount of coking coal required per tonne of coke made. The main techniques include the use of briquetted non-coking coals in the coke oven

charge, fine grinding and sizing of coal, predrying coal and dry quenching of the coke product.

The Germans have launched a major project to develop Jumbo reactors for use in cokemaking. A major benefit is the ability to make quality coke from non-coking coals.

This study forecasts that further adoption of existing technology to its coke ovens will permit the Japanese steel industry to increase the amount of new and/or weak coking coals in its coke oven charge from the 1990 industry average of 16.7% to 20% by 1995, and 25% by 2000 where it will hold to 2005. It is expected the rest of the western world will not increase its present usage of non-coking coals. By 2005, Germany is forecast to have in-place coke capacity of 4 mtpy in Jumbo reactors capable of using 80% non-coking coal in the blend. These forecasts translate into the following reduction in coking coal consumption. (Table 2.1)

Table 2.1			
	1995	2000	2005
	(million tonnes)		
Japan	1	3	3
Total Western World	1	3	8

2.4 PULVERIZED COAL INJECTION (PCI)

The injection of fuel into the blast furnace to reduce coke consumption has been widespread for some time. Natural gas, fuel oil and non-coking coals have been the dominant materials used. While coal injection requires considerably higher capital cost, for operating and technical reasons it is concluded that coal will dominate in the future.

The oil crisis caused a great upsurge of PCI in the 1970s. Interest has been recently increased because of the shortage of cokemaking capacity in the strong steel market.

On the short term, PCI is the major threat to coking coal. The steel industry worldwide is considering PCI as a vehicle to overcome the serious problem of aging coke batteries. Increasing PCI ratios permit integrated steel producers to continue to make hot metal without replacing cokemaking capacity.

While it appears that the technical limit for coal injection may be as high as 400 kg/thm¹, 300 kg/thm is a realistic limit. 300 kg/thm represents a 60% reduction of the current coke rate of approximately 500 kg/thm, assuming a coke replacement ratio of 1 t coke per 1 t PCI. Above a PCI rate of approximately 150 kg/thm, oxygen enrichment of the blast air is necessary.

This study forecasts the following industry average PCI rates. (Table 2.2)

Table 2.2			
	1995	2000	2005
	(kg/thm)		
Japan	150	200	300
Western World	80	120	175

If these rates prevail, by 2005 Japan will consume approximately 65% less coking coal than if the 1991 average coking rate of 460 kg/thm had prevailed. The corresponding figure for the western world is 35% less coking coal.

2.5 NEXT GENERATION STEELMAKING TECHNOLOGY

Three new steelmaking processes are under extensive study in Australia (Hismelt), U.S. (AISI-DOE) and Japan (DIOS). In addition the Corex process is in commercial operation in South Africa.

All four processes have in common the use of non-coking coal in a reactor to make hot metal directly from iron ore.

While the Corex process is commercially proven, it will likely have little major long term impact. The integrated producers are pinning their hopes on one of the other three approaches.

The timing for adoption of this new technology will be tied to the effective operating life of each individual steel company's coke battery and blast furnace capacities. The industry expects the technology to be ready in the 2000-2005 period and will likely be integrated into operations starting about 2005.

One Japanese source expects the "next generation" of steel capacity to include a mix of 30% electric furnace, 20% new technology and 50% conventional coke oven/blast furnace.

¹ tonne hot metal

This study assumes the impact of new technology on coking coal requirements will be 3 mtpy of hot metal made by the Corex process forecast to be on stream by 2000. This represents a loss of 2 mtpy of coking coal. Should 20% of Japan's crude steel production in 2005 be by new technology, a reduction in coking coal of a further 4 mtpy (at the then forecasted coke rate 160 kg/thm) would result.

2.6 COKE QUALITY

Some experts believe that as coke rates are decreased by PCI rate increases, the remaining coke will have to be of much higher quality. This, in turn, will increase the desirability of B.C. type coking coals. Others argue high quality coke will not be required. The issue remains to be resolved by test work.

2.7 OPPORTUNITY

The U.S. steel industry is forecast to enter a serious coke shortfall situation in the mid-1990s when aging coke batteries must close. The total world integrated steel industry faces the same situation but to a lesser degree. The production of coke in B.C. for export to the U.S. mid-west and to markets in the Pacific now supplied by Japanese coke makers may merit serious consideration. A new oven design developed in the U.S. that minimizes capital cost and pollution problems by having no by-product recovery may be an attractive option.

If the forecast of greatly expanded electric arc furnace capacity is accurate, increasing amounts of DRI (direct reduced iron) and/or iron carbide will be required. Both commodities utilize natural gas (or coal) and iron ore in their manufacture. Production of these in B.C. should be evaluated as should a mini-mill incorporating thin sheet casting.

2.8 CONCLUSIONS

Table 2.3 summarizes the coking coal reduction that might be experienced in both Japan and the total western world from changing coke and steelmaking technologies. The quantities represent the reductions in coking coal consumption that would occur relative to the situation had 1990 conditions prevailed. Japan could be using approximately 35 mtpy less coking coal by 2005; the western world, 165 mtpy less.

The two most significant changes are wider application of PCI and expansion of mini-mill capacity because of thin sheet casting. PCI is more significant in the short term; thin sheet casting, in the long term. Ultimately the new generation of steelmaking technology will dominate.

The above forecasts are quite crude, but are sufficiently accurate to indicate that changing technology will put severe downward pressure on coking coal demand and, by implication, on price. There is no single innovation under consideration by the steel industry that does not have as a major objective, the reduction of coking coal consumption per tonne of steel produced.

It appears very likely that the last integrated steelmill using coke and blast furnaces has been built, at least in the developed world. At best, coking coal can expect a flat demand in the future. Realistically, a sharp decline should be assumed in future planning by the B.C. coal industry.

Table 2.3

Summary of Forecasted Reductions in Coking Coal Demand Relative to the Situation had Present Conditions Prevailed into the Future

	Reduced Coking Coal Requirement (million tonnes)		
	1995	2000	2005
Japan			
Increased electric furnace capacity	1	2	2
Changing cokemaking technology	1	3	3
PCI	15	17	25
New steelmaking technology			4
	<u>17</u>	<u>22</u>	<u>34</u>
Western World			
Increased electric furnace capacity	19	69	82
Changing cokemaking technology	2	3	8
PCI	38	46	69
New steelmaking technology		2	6
	<u>59</u>	<u>120</u>	<u>165</u>

3 STEEL DEMAND FORECAST

The growth in crude steel production during the 1980s is shown in Table 3.3. Growth in the industrialized West was negative while that in the developing nations was dramatically positive. The total world production averaged 1% per year for the period. The biggest decline was experienced by the U.S. Japanese production declined while that of its Asian neighbours increased.

International Iron and Steel Institute, (IISI), Brussels, forecasts that the same crude steel demand pattern will continue at least until 1995 (Table 3.1): ⁽¹⁾

The Paine Weber forecast used in the B.C. Steel Study ⁽²⁾, assumed crude steel demand for the western world would grow to 2000 as follows (Table 3.2):

In its medium case, Paine Weber agrees with the IISI that world demand will be sluggish.

Dofasco expects growth in demand for the decade in the western developed world could be 0 to 1% per year and 2 – 3% per year in the total world. This indicates better than average growth is expected in developing nations. ⁽⁴⁾

A major reason for the poor outlook in the industrialized nations is the increasing trend to high strength alloys and substitution. High strength steels permit functional designs to be achieved with less weight of steel. In the past the big threat to steel was plastic. It is now aluminum. ⁽⁷⁾

Table 3.1			
Steel Demand Forecast			
	Apparent Consumption 1989	Forecast Demand 1995	Growth Rate 1989 – 1995 % Per Year
West			
Developed Nations	375	344	-1.6
Developing Nations	124	151	+3.3
	<u>499</u>	<u>495</u>	<u>-0.1</u>
East	295	305	+0.6
World	<u>794</u>	<u>800</u>	<u>+0.1</u>

Table 3.2								
Western World Steel Demand Forecast To 2000								
(million tonnes)								
	Apparent Consumption 1989 ⁽¹⁾	Actual Production		Demand Forecast				Growth Rate 1989 – 2000 % Per Year
		1989 ⁽¹⁾	1990 ⁽³⁾	1990	1991	1995	2000	
High	499	497	491	470	535	570	600	+1.8
Medium	499	497	491	420	498	500	510	+0.3
Low	499	497	491	415	370	390	400	-2.0

The aluminum industry is very aggressive and skilful at making inroads into steel markets. For example, to enter the can market, the aluminum industry started a recycling industry for empties. It took over a decade for the steel industry in North America to reply with its own recycling system.

UNITED STATES

National Steel expects U.S. crude steel production will hold in the 76 – 80 mtpy range for the period 1991 to 1996 with 1991 being 69 mt down from 77 mt in 1990. ⁽⁵⁾ The major assump-

tions behind this forecast are a 1.5 – 3% per year growth in GNP, U.S. exchange rate holds at current levels and U.S. imports and exports of steel products hold in the 3 – 4 and 11 – 14 mtpy ranges, respectively.

A significant part of the reason for such a flat forecast is stagnation in the auto industry.

The USBM⁽⁶⁾ forecasts that U.S. production of hot metal in blast furnaces (excludes electric furnace production) will be 45 – 47 mt in 1995 down from the current yearly rate of 49 mtpy.

Table 3.3
Growth in Crude Steel Production

		<u>Production</u>		<u>Increase</u> <u>%</u>	<u>Growth Rate</u> <u>1980 – 1989</u> <u>% Per Year</u>
		<u>1980</u>	<u>1989</u>		
		(Million Tonnes)			
A.	<u>West</u>				
1.	<u>Developed Nations</u>				
	Western Europe ⁽¹⁾	155	154	-1	
	Japan	111	108	-3	
	U.S.	102	89	-12	
	Canada, Australia, New Zealand, S. Africa	<u>33</u>	<u>32</u>	<u>-3</u>	
		401	383	-4	-0.5
2.	<u>Developing Nations</u>				
	Brazil	15	25	67	
	South Korea	9	22	144	
	India	10	15	50	
	Turkey and Yugoslavia	6	12	100	
	Taiwan	3	9	200	
	Other:				
	Latin America	14	18	29	
	Asia	2	5	150	
	Africa	2	4	100	
	Middle East	<u>1</u>	<u>4</u>	<u>300</u>	
		<u>62</u>	<u>114</u>	<u>84</u>	<u>+7.0</u>
	Sub-total	463	497	7	+0.8
B.	<u>East</u>				
1.	USSR	148	160	8	
2.	China	37	61	65	
3.	Eastern Europe ⁽²⁾	61	59	-3	
4.	North Korea	<u>6</u>	<u>7</u>	<u>17</u>	
		252	287	14	+1.5
C.	Total World	715	784	10	+1.0
(1) Excludes Turkey and Yugoslavia.					
(2) Includes East Germany					
Source: IISI					

JAPAN

Japan is currently the world's high cost producer of crude steel. This is largely the result of the strong yen. In spite of this, in 1988, 1989, and 1990 crude steel production reversed the decline of the 1980s and reached unexpected high levels:

Table 3.4			
Japanese Crude Steel Production			
1980 - 1990			
(million tonnes)			
CY Years	Production	Imports	Exports
1980	111	1	30
1985	105	3	32
1986	98	3	29
1987	96	5	25
1988	106	7	23
1989	108	7	20
1990	110	12	17

In the last three years imports of steel products have increased and exports declined quite dramatically. Table 3.4)

The increase in steel production in 1988 - 1991 was because of large domestic demand. The Japanese themselves, as well as other steel experts,

do not expect this high level of production to be maintained.

National Steel believes Japanese domestic auto market is saturated and only the replacement market exists. To compete in the 1980s in the U.S./Canada auto market in the face of a strong yen, the Japanese auto makers moved manufacturing to North America. Currently one in five autos made in the U.S., is by a Japanese or South Korean company. While these cars still contain some Japanese steel, the quantity is obviously less than in cars imported from Japan. For example, Honda buys 75% of the steel used in its U.S. made cars from U.S. steelmills; other companies as little as 25%.⁽⁵⁾

In the 1990s the Japanese will likely continue to attempt to penetrate the North American market from plants erected in the U.S., Canada and Mexico. There is little doubt they will accelerate this practice in Europe, perhaps through plants in Eastern Europe.

As demonstrated above, Japanese exports are declining and imports increasing. In Table 3.5, the Japanese situation is compared with that of its neighbours in Asia who, in the past, have been big markets for Japanese semi-finished steel products.

Table 3.5										
Imports and Exports of Steel Products in Asia										
(million tonnes)										
Year	Japan		South Korea		Taiwan		China		Other Asia	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
CY 1980	1	30	2	5	3	1	5	0.4	12	1
1981	2	29	2	5	2	1	3	0.6	14	1
1982	2	29	1	6	2	2	4	1.1	16	1
1983	3	31	2	6	1	2	10	0.5	15	1
1984	4	32	3	6	2	2	13	0.2	13	1
1985	3	32	3	6	1	2	20	0.2	13	1
1986	3	29	3	6	2	1	19	0.2	14	1
1987	5	25	4	6	4	1	12	0.3	14	2
1988	7	23	3	7	6	2	9	0.7	15	2
1989	7	20	4	7	6	2	7	0.5	16	3
1990	12 ⁽¹⁾	17 ⁽²⁾								

(1) 25% South Korea, 17% Brazil, 14% USSR, 8% China, 5% Taiwan, 5% U.S., 5% South Africa, 3% Australia, 18% other.

(2) 19% U.S.; approximately 10% each to China, Thailand, South Korea and Taiwan; 40-50% others.

Prime Source: IISI

Japan's neighbours, with the exception of Taiwan, have reduced imports and/or increased exports.

The Japanese intend to offset the decline in volume of steel being exported by exporting higher value steel products, such as high strength sheet and precision finished shapes, and thereby maintain or increase foreign earnings.

NKK in 1989 forecast the high production levels of 1988 and 1989 could not be maintained and expected crude steel production to hold in the 90 – 95 mtpy range for 1990 – 1995. ⁽⁸⁾ North American experts generally agree that Japan will have difficulty maintaining production at the 100 mtpy level.

SOUTH KOREA

South Korea by 2000 could be producing close to but still under 30 mtpy crude steel. ⁽⁴⁾⁽¹⁰⁾ The U.S. Department of Energy doubts if this can be achieved because exports of steel products will have to constitute such a major fraction of exports (34% in 1988). ⁽⁹⁾ Forecasting South Korean production is difficult as the level will be determined for political and not economic reasons; for example, exports may be subsidized to aid employment.

TAIWAN

No expansion of crude steel production is likely. ⁽⁵⁾⁽¹⁰⁾ Dofasco thinks that because Taiwan imports such a major share of its steel needs, it will likely consider capacity expansion should world steel prices increase significantly over the levels of the last few years. Otherwise it will continue to import. ⁽⁴⁾

EUROPE

No expansion is expected in western Europe except perhaps for mini-mills in Italy and Spain. A big uncertainty is what will happen in Eastern Europe. No forecasts were forthcoming.

3.2 FORECAST

The following forecast for crude steel production to 2005 in western nations is used in this report:

This forecast is based on Paine Weber's middle range for western world production of 500 and 510 mt production in 1995 and 2000, respectively. ⁽²⁾ Superimposed on this forecast is National Steel's 1995 U.S. production forecast of 70 mt ⁽⁵⁾ and NKK's 1995 Japanese production forecast of 95 mt. ⁽⁸⁾ The forecast for 2005 simply assumes the developed nations show no change from 2000 but the developing nations continue to grow at 4.1% per year. (Table 3.6)

Table 3.6
WESTERN NATIONS CRUDE STEEL PRODUCTION TO 2005

	Million Tonnes				Growth Rate % Per Year		
	1989	1995	2000	2005	1989-1995	1995-2000	2000-2005
a) Developed Nations							
Japan	108	95	88	88	-2.2	-1.5	0.0
U.S.	89	70	65	65	-4.1	-1.5	0.0
Other	186	180	167	167	-0.6	-1.5	0.0
	383	345	320	320	-1.7	-1.5	0.0
b) Developing Nations	114	155	190	230	+5.3	+4.1	+4.1
Total	497	500	510	550	+0.1	+0.4	+1.6

REFERENCES TO SECTION 3

- (1) IISI Annual Report, October, 1989.
- (2) B.C. Steel Mill Preliminary Market Study, AEC, Resource Consultants Ltd., for B.C. Ministry of Regional and Economic Development, March, 1990.
- (3) Iron and Steel Consolidation and Modernization, W.T. Hogan, EMJ, March, 1991.
- (4) Interview D.N. Eastman, Dofasco, during this study.
- (5) Interview J.A. Rainis, K.P. Hass, National Steel, during this study.
- (6) Interview T. Peters, USBM, during this study.
- (7) Interview W. Dennis, AISI, during this study.
- (8) M. Hashimoto NKK Corp., Canadian Coal Conference, May, 1989.

4 ELECTRIC ARC FURNACE STEEL PRODUCTION

4.1 MINI-STEEL MILLS

The electric arc steelmaking furnace using iron and steel scrap as feed was invented in 1881. It was not until the 1960s that it entered widespread use. This resulted from the introduction of Basic Oxygen Furnace (BOF) to replace the open-hearth furnace for converting hot metal to steel. The open-hearth furnace could be run with any amount of scrap from 0 to 100%. The BOF is limited to about 30% scrap feed. The resulting surplus of scrap presented an opening for mini-steel mills in regional markets.

These changes are demonstrated by the following data for the U.S.: (Table 4.1)

	Electric Arc	BOF	Open-Hearth
1965	18 (1968)	17	
1973	19	55	26
1989	36	60	4

Mini-mills have expanded around the world. Table 4.2 shows that the electric arc furnace represents almost 32% (1989) of all crude steel made in the western world and 27% of the total world. It is more widely used in the developing world where 35% of steel is made with this technology compared to 31% in the developed nations (west only).

The mini-mill is a significantly less capital intensive way of entering the steel business than through the integrated coke/blast furnace route. As an example, between 1981 and 1988 Turkey doubled its steel capacity from 4.3 to 8.6 mtpy almost exclusively with mini-mills.

The other major advantage of the mini-mill is it can realize competitive costs at production levels in the 0.5 – 1.0 mtpy range. The minimum sized economic integrated mill is 2.5 – 3 mtpy.

Mini-mills have grown up largely to service a localized market. They generally depend on the same local area for scrap feed. Mini-mills have difficulties competing with integrated producers in distant markets and/or when they must reach outside for scrap.

Mini-mills to date have been limited to low quality products, such as concrete reinforcing rod, angle iron, I beams, etc. Mini-mills have pushed the integrated mills out of the low end of the market. However, they have also thereby saturated the markets available to them. For growth to occur in industrialized nations, the mini-mills must move into flat rolled, sheet products, the last preserve of the integrated producers.

4.2 NUCOR CORP. ^{(1) (2)}

Nucor Corp., a U.S. mini-mill steel company with four plants of 2 mtpy combined capacity, in 1989 brought on a new 0.7 mtpy mini-mill at Crawfordsville, Indiana that appears to have opened up the flat sheet market to mini-mills.

Nucor working with a German engineering company has succeeded at Crawfordsville to continuously cast a 25 mm thick plate directly from molten steel. The steel industry has been trying unsuccessfully for two centuries to achieve this.

Conventionally, hot metal has been cast into slabs 200 – 250 mm thick. These are then reduced down to hot-band steel on a hot rolling mill. Hot-band steel can then be moved to cold rolling mills. Because of capital cost, hot rolling mills are economic only at large throughput rates of 2 – 3 mtpy. The significance of Nucor's success is that sheet manufacture has now been divorced from the hot rolling mill and has made small rolling mills economic.

Nucor's plant opened in the second half of 1989 and in June, 1990, had its first profitable month. The plant cost U.S. \$270 million, including U.S. \$50 million for a cold rolling mill. By March,

Table 4.2
World Crude Steel Production by Process (1989)

	Electric Arc Furnace	B.O.F.	Open Hearth	Other	Annual Crude Steel Production mt
Developed Nations					
Western Europe excluding Spain, Italy	20.6	79.4			114.1
Spain, Italy	55.8	44.2			38.0
U.S.	35.9	59.6	4.5		88.9
Canada, Australia, New Zealand, South Africa	27.0	72.6		0.4	32.4
Japan	<u>30.6</u>	<u>69.4</u>	<u> </u>	<u> </u>	<u>107.9</u>
Sub-total	31.1	67.9	1.0		381.1
Developing Nations					
Turkey, Yugoslavia	49.0	39.6	11.4		12.5
Brazil	22.7	74.6	-	2.7	25.0
Other Latin America	54.7	36.0	9.3		16.3
India	26.5	39.4	34.1		14.4
South Korea	29.5	70.5			21.9
Taiwan	<u>33.7</u>	<u>66.3</u>	<u> </u>	<u> </u>	<u>9.1</u>
Sub-total	35.4	56.1	7.8	0.7	99.2
Total West	31.7	65.6	2.5	0.2	480.3
Eastern Europe	15.0	37.6	47.4		219.1
Total	26.5	56.8	16.6	0.1	699.4
Source: IISI					

1991, the company reports long term debt of \$28 million and has announced it will construct a second mill (0.9 mtpy) using the same technology for start-up mid-1993 (\$300 m). It appears that Nucor now sets the price for hot band steel.

A plant using a similar process to that of Nucor is to open in Italy in the fall of 1991.

Nucor claims its cost of sheet is U.S. \$55 to \$80 per t, less than that of an integrated mill because of savings in labour, energy and feed material costs. The press reported that Nucor manufactures finished cold rolled sheet for U.S. \$255 per t compared to the next lowest cost U.S. producer, Bethlehem Steel, at U.S. \$325 per t.⁽⁴⁾

The steel industry agrees the Nucor process works technically and economically but differs on how successful it will be in opening the flat sheet market to mini-mills. Some people think that the process will never be able to make deep-drawn flat products requiring good surface appearance, e.g., exterior auto panels. Others say it is only a matter of time until the technical problems are solved and mini-mills will be able to compete in any product line.⁽³⁾ Nucor is confident of success and is already competing for some auto business.⁽¹⁾

Even some integrated producers are evaluating the Nucor approach. One integrated steel company interviewed mentioned that, were it interested in an expansion, it would look seriously at a Nucor type plant.

There is considerable worldwide interest in making continuous plate even thinner than Nucor's 25 cm. The ideal is to continuously cast a sheet that is ready to use even without cold rolling. The Canadian steel industry, government and several universities have embarked on Project Bessemer, a 5 year \$40 – 50 m study to attempt to cast 2-5 mm thick sheet.⁽⁶⁾ The Japanese, German, Swedish, Austrian and U.S. steel industries all have programs to develop thin strip continuous casting. Chapparral, a U.S. mini-steel company, is experimenting with making sheet by spraying molten steel into a final shape.⁽⁵⁾

4.3 SCRAP

There are three basic types of iron and steel scrap:

(i) Obsolete

- scrapped autos
- reclaimed beams
- tin cans
- landfill type scrap

(ii) Revert

- edging, trimmings from manufacturing operations, e.g., 5 – 10% of the plate used for stamping out cans is waste as is 25% of the sheet used in auto manufacturing.

(iii) Internal

- scrap generated within the steelmill.

Continuous casting, which has been widely adopted by the steel industry, has greatly reduced the amount of internally generated scrap at integrated producers which, in turn, has pushed them back into the market for scrap. For example, in 1970, 60% of the scrap consumed in the U.S. by integrated steelmills was internal scrap. By 1990 this had dropped to 27%. (Table 4.3)

The U.S. is the world's largest exporter of scrap. Data for 1988 (Table 4.4) show that the U.S. exported 9 million t of scrap, or 24% of all scrap

Table 4.3

Continuous Cast Steel % of Total Crude Production

	Japan	U.S.	Total Western Countries
1965			1
1980	60	20	39
1989	94	65	81

traded among nations. The U.S. provided 33 to 60% of Japanese, South Korean, Turkish, and Taiwanese scrap imports. These countries account for over 25% of scrap traded. The largest scrap importing nations are Italy and Spain with 25% of the total between them. The developing nations are much more dependent on scrap imports (50%) than are the developed nations (11%).

4.3.1 Scrap Quality

The limiting factor on the Nucor approach to flat products is not the quantity of scrap available, but its quality. All people interviewed in the

Table 4.4
Iron and Steel Scrap Consumption and Sourcing (1988)

	Total Scrap Consumed mt	Scrap Imported			
		Total		From U.S.	
		mt	%	mt	%
A) Developed Nations					
Western Europe					
Italy, Spain	24.8	9.6	39	0.5	5
Other	49.2	7.2	15	—	—
	74.0	16.8	23		
U.S.A.	69.7	0.9	1		
Japan	43.0	1.8	4	0.6	33
Canada	8.5	1.2	14	0.6	50
Australia, New Zealand, South Africa	5.6	0.6	11	—	—
	200.8	21.3	11		
B) Developing Nations					
Latin America					
Mexico, Venezuela	4.7	1.5	32	1.1	73
Other	10.6	0.4	4	—	—
	15.3	1.9	12		
India	4.1	0.9	22		
South Korea	4.1	3.9	95	2.1	54
Turkey	2.5	3.0	120	1.8	60
Taiwan	2.0	1.3	65	0.6	46
Yugoslavia	1.5	0.7	47		
Other Middle East, Africa	-	2.9			
	29.5	14.6	50	—	—
Total West	230.3	35.9	16		
C) Eastern Block					
USSR	72.0	-	Nil		
Eastern Europe	29.8	1.0	3		
China	12.7	0.5	4	—	—
	114.5	1.5	1	—	—
Total World	344.8	37.4	11	9.1	24

Source: Iron and Steel Scrap 1989 Yearbook, USBM;
Steel Statistical Yearbook, 1990, IISI.

study agreed with this conclusion.

Figure 4.1 compares the impurities present in various major categories of scrap with impurity specifications for the major steel products. It would be impossible to make auto body sheet, for example, using 100% #1 bundles, the best scrap available in reasonable quantity.

The only way mini-mills can, therefore, penetrate the sheet markets, even if successful in perfecting the casting technology, is by adding some virgin iron to their furnace charge. Virgin iron is made directly from iron ore and, consequently, does not contain the recycling impurities present in scrap.*

4.4 SOURCES OF VIRGIN IRON

There are three products under consideration for use as virgin iron to dilute scrap feed to electric arc furnaces. There are Direct Reduced Iron (DRI), iron carbide and hot metal made by the Corex process.

4.4.1 DRI

DRI is a well established commercial product with worldwide installed capacity of about 23 mtpy in 16 countries. It is made by contacting iron oxide ore with reducing gases (carbon monoxide and hydrogen) in a fluidized bed, a shaft furnace or a rotary kiln. The source of reducing gas for the fluidized bed and the shaft furnace process is natural gas; for the rotary kiln, coal.

The most widely used process is that developed by Midrex which uses the shaft furnace. Any future plant would likely employ Midrex technology.

* The most serious impurity is copper, followed by tin. Chromium, nickel and molybdenum are also building up in recycling scrap but are not as harmful as copper and tin. These latter two impurities cause hardening of deep drawn sheet resulting in cracking and breakage. Technology exists⁽⁴⁾ to remove these impurities but it is prohibitively expensive.⁽⁸⁾ The only solution is dilution. Zinc and lead are reaching troubling levels but they can be removed during furnacing.

Midrex Corp. (owned by Kobe Steel) has developed a new process for making DRI with coal, the Fastmet Process. Fine iron ore and coal are pelletized with a bentonite binder and then heated in a rotary hearth furnace. Midrex is contemplating a 150 – 200,000 tpy demonstration plant.

DRI manufacture requires low cost natural gas. Consequently, new plants can only be considered in natural gas producing countries. This is demonstrated by Figure 4.2.

DRI is pyrophoric and must be used at site. For shipment it is hot briquetted (HBI).

Based on data provided by Midrex, the cost of HBI in B.C., using an iron ore cost of U.S. \$50 per t, and natural gas at U.S. \$1.85 per MCF, calculates out at U.S. \$147 per t, including overhead and capital charges.⁽⁹⁾ HBI sells for a premium of approximately U.S. \$20 per t over the price of #1 grade scrap. Midrex thinks a realistic price to assume for HBI is about U.S. \$110 per t, fob B.C. plant.

These figures indicate a HBI plant based on the assumed B.C. natural gas and iron ore costs would not be economic. The use of coal would reduce the cost by about \$10 per t. The cost of hot briquetting is also about \$10 per t. If DRI was made with coal and fed directly to a mini-mill at site, it might be possible to achieve acceptable economics.

Worldwide there are four natural gas based plants under construction. Midrex has just signed a contract to build a plant and three more are close to signing. These seven plants have a combined capacity of 7 mtpy compared to 1990 production of 18 mtpy, a 40% increase.

Nucor is looking at DRI manufacture in Venezuela and Oregon.

4.4.2 Iron Carbide

Iron Carbide Holdings Ltd., Australia, has the rights to a process to make iron carbide. It has an agreement with American Iron Carbon Corp., Chicago, to produce at two locations in North and South America to a minimum capacity of 0.35 mtpy each. No construction plans have been announced.

Figure 4.1

SCRAP and MAJOR STEEL PRODUCTS:

Comparison of Maximum Residual Impurity Levels

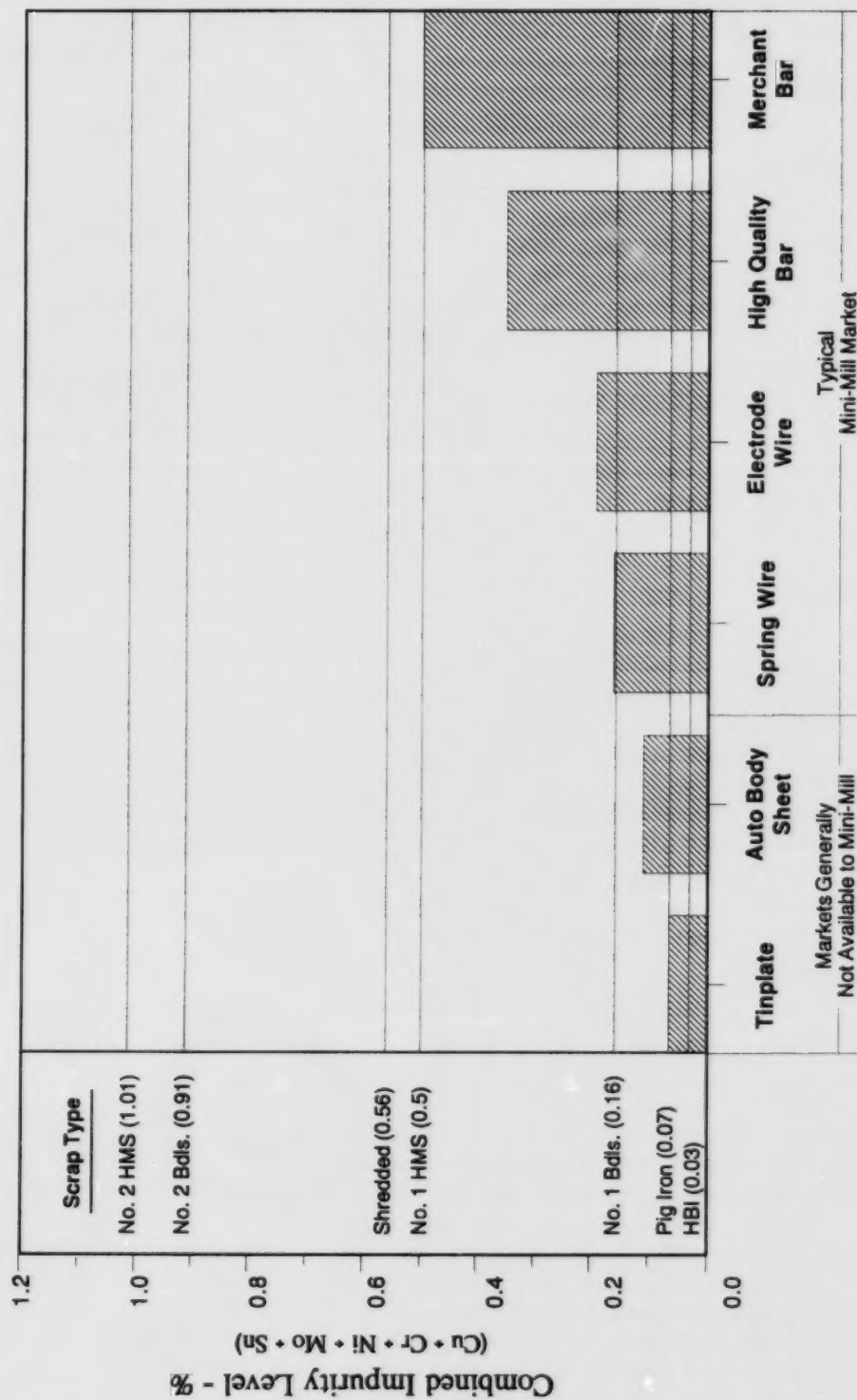
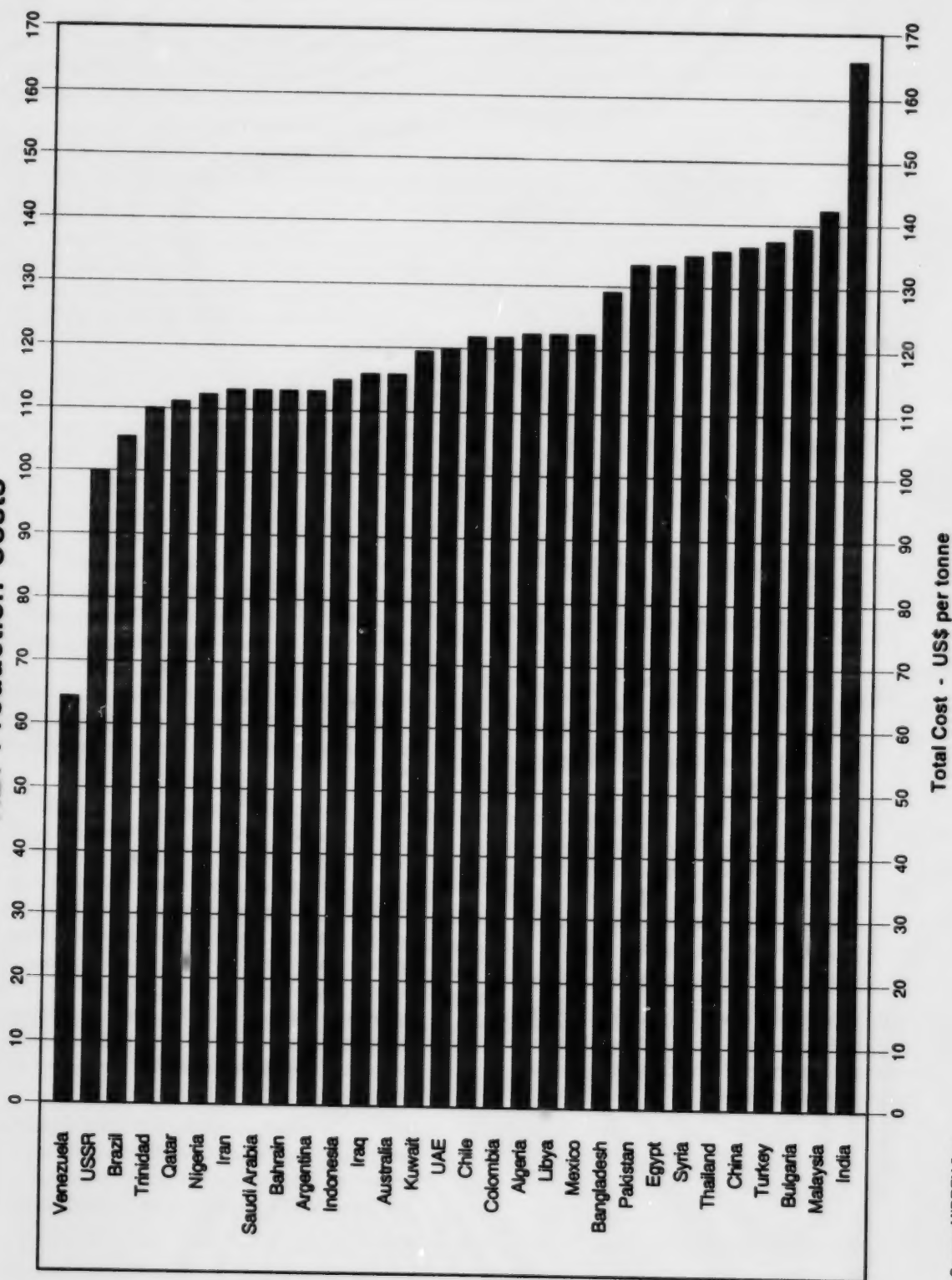


Figure 4.2

HBI Production Costs



Source: MIDREX Corp.

The process was developed at Hazen Research in Colorado and consists of contacting iron ore in a fluidized bed with reformed natural gas. The resulting iron carbide is a stable crystalline product containing approximately 93% iron, 7% carbon.

In 1988, melt-size samples were produced for testing by potential customers.

American Iron Carbide claims the major advantages of the product relative to DRI are: ⁽¹⁰⁾

1. Stable, non-pyrophoric products that do not require briquetting.
2. The carbon content acts as a fuel in the electric furnace, thereby reducing electricity consumption.
3. Is made from iron ore fines not the more expensive briquetted or lump ore.
4. Lower fuel demand as the reaction temperature required is lower (by 400 – 700°F).
5. Direct production cost two thirds that of HBI.

Some of the doubts expressed about the product are:

1. Amount that can be used in an electric arc furnace is restricted by the high reactivity of the material. The limit is probably below 25% and realistically may be only about 8 – 9%.*
2. Production requires a very large diameter fluidized bed which will be difficult to operate reliably with uniform conditions. Without close control free iron is produced. If this free iron content is over 2 – 3%, the product is pyrophoric.
3. Process is still in development phase.

Midrex thinks the cost of iron carbide will be very similar to that of HBI because it must also use reformed natural gas. The reforming unit is a major capital cost item.

* To make quality sheet products will require dilution of scrap with 20 – 40% virgin iron.

4.4.3 Corex

The Corex route to hot metal is discussed in Section 7, New Steelmaking Technology. It has merit as a replacement for aging blast furnace capacity in the interval before new steel making technology is perfected.

4.5 OUTLOOK FOR ELECTRIC ARC FURNACE EXPANSION

Considerable growth of mini-mill capacity is expected in developing nations to meet projected growth in steel demand. Mini-mills are significantly less capital intensive, have much lower economic throughput rates than integrated mills and are much quicker to build.^{(8) (12) (13) (14)}

To 1995 the impact of continuous casting of thin sheet suitable for cold rolling (i.e. Nucor type plant) will be real but not major. In the long term, if the ability to produce quality sheet is proven, the impact could be very significant.

By 1995 the U.S. may add 3 – 5 mtpy of Nucor type capacity^{(8) (11)}, increasing electric furnace share of production of crude steel from 38 – 39% now to approximately 45% (allowing for some BOF closures as well). With the exception of Spain and Italy, where electric furnace production is well established, little change is expected in Western Europe. Similarly, Japan and South Korea have surplus and/or modern rolling capacity and will not likely install Nucor type technology.^{(8) (11) (13) (14)}

Long term forecasts are very difficult to make because of the uncertainty concerning the probable success of thin plate or “near net” casting. Should it prove successful, the consensus was that inroads of by-electric furnaces would be major. As one person said, it would “stand the integrated mills on their ears.” Only two concrete forecasts were forthcoming from the interviews for 2000: Japan would increase electric furnace crude steel production from 31% in 1989 to 35% and that western world electric steel furnace share would increase from 32% in 1989 to 50%.

The forecast of electric furnace share of total crude production developed in this study is shown in Table 4.5. Assuming present coke rates for Japan and the western world of 460 and 500 kg/

thm, respectively, and a coal to coke ratio of 1.5 t coal per t coke, this forecast translates into the following reductions in coking coal consumption compared to what would have been the situation if today's conditions had prevailed: (Table 4.6)

Expansion of thin sheet casting sheet will produce an expanding market for virgin iron. This will be either HBI or iron carbide. At this stage, it appears HBI has the edge.

Table 4.6			
Reduced Coking Coal Consumption			
	(mt)		
	1995	2000	2005
Japan	1	2	2
Western World	20	69	82

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Table 4.5
Forecast of Electric Furnace Share of Total Crude Steel Production

Table 4.5												
Forecast of Electric Furnace Share of Total Crude Steel Production												
	1989			1995			2000			2005		
	Electric Furnace Share %	Crude Steel Production		Electric Furnace Share %	Crude Steel Production		Electric Furnace Share %	Crude Steel Production		Electric Furnace Share %	Crude Steel Production	
		Total mt	Blast Furnace mt		Total mt	Blast Furnace mt		Total mt	Blast Furnace mt		Total mt	Blast Furnace mt
Developed Nations												
Japan	31	108	75	32	95	65	**35	88	57	35	88	57
U.S.	36	89	57	*45	70	39	55	65	29	55	65	29
Other	29	186	132	33	180	120	50	167	84	55	167	75
	31	383	264	35	345	224	47	320	170	50	320	161
Developing Nations												
	35	114	74	41	155	91	55	190	85	55	230	104
Total West												
	32	497	338	37	500	315	**50	510	255	52	550	265
* National Steel forecast												
** Dofasco forecast												

* National Steel forecast

** Dofasco forecast

5 CHANGING COKEMAKING TECHNOLOGY

5.1 GENERAL

Seventy percent (in Japan) of the cost of manufacturing coke is the cost of coal. The industry has been attempting to reduce this cost by developing technologies to permit increased use of lower cost coals.

Also to reduce costs and to improve emission controls, instrumentation of coke ovens has been improved and better methods of cooling coke have been implemented. The Japanese are in the forefront of such changes.

The West Germans have recently constructed higher and wider coke ovens to reduce capital and operating costs. These design modifications have culminated in the so-called "Jumbo Reactor".

The impact of all these developments is to reduce the amount of coking coal used in steelmaking. Japan is the leader in this approach.

5.2 CHANGES IN CONVENTIONAL COKEMAKING

The Japanese steel industry uses some 90 different coals from six countries. A typical coke oven charge contains 10 – 15 coking coals. Blending, while it minimized the overall cost of coking coals charged to the ovens, rarely enabled low cost coals to be included. For this, a number of coal pretreatment techniques have been adopted.

5.2.1 Coal Pretreatment

It has been found that the higher the density of the coal blend charged to an oven, the stronger the resulting coke.⁽²⁾ High density can be achieved by grinding feed coal to a more uniform, small particle size, by briquetting part of the charge, by adding binders to the charge and by preheating the charge.

Pre-Grinding

In Japan and USSR⁽²⁾ crushing and grinding of charge coals is widely used to control grain size and maximize charge density. Using this practice coke strength can be increased by 1 – 2 points. As a result, while maintaining the same coke strength level, 5 – 10% non-coking coal can now be used.

Briquetting

In cokemaking, coals soften and melt at temperatures in the 350 – 500° range and solidify into hard coke at about 1000 – 1100° C, after volatile matter has been expelled and reactions within the softened/melted coal are complete. Weak and non-coking coal do not melt and form strong lumps of hard coke. They simply char and remain as discrete particles. To achieve hard coke formation with such coals, they must be pressed into high density briquettes before charging and/or a pitch or tar added to the coal blend to bind the char particles as they form.

Briquetting was introduced into Japan in 1973 in response to the first oil crisis. Today some 40% of total Japanese coke production (1988) is made with a mixture of 30% briquetted coal / 70% ground powdered coal. The briquette generally contains 6% pitch as binder. Some 10 plants produce 8.4 mtpy of briquettes for cokemaking. This has allowed inclusion of 15 – 20% weak coking and non-coking coals in coke oven charge. It also helps in the production of strong coke when using low fluidity coking coals.

A similar effect is achieved by stamping the coal charge into large blocks using binders. This is practised in France and is under testing in Japan and India. Stamping can increase the density of the charge from the typical value in Japan (without pre-grinding) of 0.7 t/m³ to 1.0 t/m³. As such, the technique permits increasing the ratio of

weak coking and non-coking coals in the blend. A problem is how to introduce large blocks into the ovens and not increase air emission problems.⁽²⁾⁽³⁾ In addition, the process is capital intensive.⁽³⁾

Only the Japanese use briquetting. There is less incentive to use the technique where high-fluidity coals are in ready supply, i.e. in Eastern U.S. and Europe. The principal reason believed for its wide adoption in Japan was not as a vehicle to increase the amount of non-coking coals used, but rather as a route to overcome the fact that Japan's coking coal blends suffer from average low fluidities.

Binder Addition

Binders made from asphalt have been used by one Japanese coke maker since 1976. By combining coal briquetting plus binder addition to the whole oven charge, the ratio of non-coking coals has been increased to as high as 26%⁽¹⁾.

Pre-Heating

Coal blends to ovens in Japan generally contain 9% moisture. By pre-drying to 150 – 300° C, the moisture is reduced to 5%. The result is an increase in density of the coal charge by 10%, an improvement in coke strength and reduced cokemaking costs (40% increase in oven productivity⁽²⁾). The coke oven is a very inefficient vehicle for removing moisture because of poor heat transfer characteristics. The process is only used at two coke plants (Nippon Steel⁽¹⁾⁽⁴⁾ and NKK Corp.)⁽⁵⁾. Pre-heating allows 25% of the coal charge to be non-coking coals.⁽¹⁾

At one time this technology looked very promising but it has not been widely adopted. There are explosion problems in handling the dried material.⁽³⁾ Also high oven wall pressures resulting in increased maintenance costs have been experienced.⁽²⁾ At the NKK installation, pre-drying has been combined with dry coke quenching. The heat recovered in dry quenching is used to dry the coal.

5.2.2 Improved Coke Oven Control

The heat for coking coal is supplied by burning non-coking coal or some other fuel in a separate chamber. The hot gases so produced pass through passageways in the common walls between coke ovens. Heat is transferred to the coal

charge in the ovens by conduction and radiation through the oven walls.

In recent years, close monitoring of fuel addition and hence temperature has been adopted resulting in reduced fuel cost and improved coke quality. These techniques have the potential to increase the ratio of non-coking coals.⁽¹⁾ Nippon Steel, who installed such controls on its 21 coke batteries has reduced heat consumption in cokemaking from 605 to 577 kcal/kg coke.⁽⁶⁾

5.2.3 Dry Quenching of Coke

In normal operation the hot coke is pushed from the coke ovens and falls down a ramp into a water basin for quenching. This step is a major source of air pollution, a waste of heat and results in coke loss due to combustion.

To cut emissions and recover sensible heat, dry quenching with air in a closed chamber has been developed. Dry quenching has a number of benefits:

- (1) Produces stronger coke by controlled cooling.
- (2) Less polluting.
- (3) Improves blast furnace performance as the coke is dry.
- (4) Recovers waste heat.

To fully benefit from the technology it is necessary to make use of the heat recovered, e.g., by electricity generation or preheating the coal charge to coke plants. This requires a large capital investment.

To date, 34 dry quenching units have been installed in Japan and 65% of all coke is now treated this way.⁽⁵⁾ There were 29 units in 1986.

Dry quenching permits the ratio of non-coking coals used to be increased by 3 – 5%.⁽⁴⁾

5.2.4 Impact on Coking Coal Demand of Changes at Conventional Cokemaking Plants

The adoption of briquetting, pre-drying, dry coke quenching and better coke oven control has had the direct effect of allowing the coke manufacturer to use weak-coking and/or non-coking coals in increasing quantities and still produce quality coke.

In summary, the various technologies have the potential to increase the ratio of weak-coking and non-coking coals in the charge to a coke oven by the following amounts: (Table 5.1)

Table 5.1	
	%
Grinding and sizing	10
Briquetting	20
Pre-heating	25
Binder Addition	26
Coke dry quenching	6

These effects are obviously not cumulative or their implementation would essentially eliminate the need for coking coals.

To date the adoption of these techniques has been limited principally to Japan. The impact

is shown on the Japanese import statistics for weak coking coal (Table 5.2). The table shows a steady increase in the ratio of weak to true coking coals in the Japanese steel industry rising from 10.7% in 1985 to 16.7% in 1990, an increase of 56% over the five year period.

Nippon Steel states⁽¹⁾ that skilful application of these technologies can raise the ratio of non-coking coals to 30 – 35%. This upper limit is influenced by size and operating characteristics of the blast furnace using the coke and properties of the coking and non-coking coals used. Most Japanese steel companies quote figures of 20 – 25% replacement of coking coals.^{(4) (7)}

CANMET believes the limit to be about 20% and will be lower if the industry requires high strength coke in the future in response to increased use of PCI.⁽²⁾ CANMET is initiating a testing program to determine the limit. In 1989, an

Table 5.2
Japanese Use of Weak Coking Coals in Cokemaking
(Million Tonnes)

JFY	Total Coal used in Coke Making	Weak Coking Coal ⁽¹⁾			Ratio Weak Coking to Total Coal Used in Coke Making (%)
		Purchased by Steel Industry	Used for PCI ⁽²⁾	Used for Coke Making (by difference)	
1980	64.9	1.4 ⁽³⁾	Nil	63.5	0.0
1985	64.7	8.1	1.2	6.9	10.7
1986	58.8	8.8	1.8	7.0	11.9
1987	60.4	10.0 ⁽³⁾	2.3	7.7	12.7
1988	63.2	12.2 ⁽⁶⁾	2.2	10.0	15.8
1989		14.0 ^{(3) (4)}	3.4 ⁽³⁾	10.6	
1990	65.2 ⁽⁴⁾	14.7 ^{(4) (5)}	3.8 ⁽⁴⁾	10.9	16.7

Source: Tex Coal Manuals.

(1) Japanese commonly refer to these as semi-soft coking coals.

(2) Pulverized coal injection directly into blast furnace.

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(5) 1.5 mt of weak coking coals were purchased in 1990 from Canada. None was used for PCI.

(6) 74% Australia, 14% South Africa, 8% Canada, 3% U.S., and 1% others.

Australian coal producer estimated the Japanese industry will go to ratios of 25 – 30%. BHP/Utah⁽⁸⁾ is of the opinion 20% can easily be achieved. Liddell Joint Ventures (Australia) believes that the Japanese will level off at a ratio of about 20% weak coking with half of this 20% being high volatile, New South Wales semi-soft coking coals and half low-to-medium volatile weak coking coals such as produced by Canada⁽⁹⁾.

The Japanese steel industry state they wish to increase the ratio over 20% but lack the technology at this point to do so⁽¹¹⁾. Up to the 20% level the Japanese are convinced the savings resulting from the ability to use non-coking coals justifies the capital cost of the technology⁽¹¹⁾.

There appears little likelihood that significant use of the technologies will occur outside of Japan. Brazil may be an exception because it largely employs Japanese steel making technology. In 1986 Kawaski Steel, partner in a major steelmill in Brazil, asked its partners to reduce costs by using weak coking coals.⁽¹⁰⁾

Briquetting, if used in the U.S., would impact significantly on the amount of steam coals that can be used in cokemaking. However, the price differential in the eastern U.S. between steam and coking coals has eroded to such a degree that little incentive exists to commit the capital required^{(11) (12) (13) (14)}. Stelco considered dry quenching but economics were not there. Electricity costs are too low in Ontario to justify the capital investment required to utilize the large volume of by-product heat generated.⁽¹⁴⁾

West Germany may adopt these technologies primarily as a vehicle to permit continued use of German coals in steelmaking.

The most recently constructed integrated steelmill was in South Korea (1990). It uses conventional coal charging technology. If the target is a coke with a high hot strength, non-coking/weak coking coals cannot constitute a significant part of the coal charge unless pitch is added. Pitch is an expensive item in most countries.⁽²⁾ It is likely these reasons convinced Pohang to stick with the conventional system.

Tata Iron in India carried out a major evaluation of technologies to improve its coke

quality. Pre-grinding, briquetting and stamping were investigated. Stamping was chosen, and is being installed, as the most suitable for India considering capital and operating costs and coke quality improvement.⁽³⁾

5.3 FORMCOKE

In the formcoke process non-coking coal is briquetted and carbonized in a shaft furnace. The coked briquettes pass into a cooling zone and are cooled to 100°C before discharge. The resulting formcoke, mixed with conventional coke, is then fed to a blast furnace.

Some 20 different processes have been proposed. They vary primarily on the type of binder used to form the briquetted feed for carbonization⁽¹⁶⁾. Only two processes are of any note. In Europe the ANCIT process has operated commercially since 1967 (accumulated production 1.5 mt). Its briquetted product is sold as smokeless fuel. It has been used successfully on a trial basis as the reductant in a blast furnace, but appears not to be a contender for wide application in the steel industry.⁽¹⁶⁾

The other process is that developed by Nippon Steel in Japan and later piloted by a consortium of Nippon Steel, Kawaski, NKK and Kobe under the sponsorship of the Japan Iron and Steel Federation. A 200 tpd pilot plant operated in 1984 – 1986 and the product was fed to a commercial blast furnace. A coke/formcoke mix up to 30% formcoke was tried successfully. In the pilot plant the usual coal feed to the process contained 60 – 80% non-coking coals with 100% non-coking feed performing successfully.⁽¹⁶⁾

Economic evaluation of a 1.1 mtpy plant concluded the process was competitive with a conventional coke plant. "At a price differential (coking coal 100 and non-coking coal 77) the process is estimated to be 15% cheaper to operate in both facility costs and manufacturing costs than the conventional coking process"⁽¹⁾

The advantages of formcoke are:

- (1) Ability to use low cost non-coking coals.
- (2) Lower operating cost.
- (3) Reduced pollution.
- (4) Easy to shut-down and start-up.

In spite of these advantages, there are no plans in Japan to build a formcoke plant. The stated reason is that PCI has relieved the pressure on cokemaking capacity.⁽¹⁾ However, a plant might still be justified should a company's coke battery reach the end of its life well before new steelmaking technology becomes available. Stelco reports that Kawasaki Steel is considering a formcoke plant because of old ovens.⁽¹⁶⁾

Dofasco doubts there will be much interest in formcoke in the future. The whole thrust of research and development is to divorce steelmaking from coke entirely.⁽¹⁷⁾

The USSR in 1988 was reported to be constructing its first formcoke plant.⁽⁶⁾

5.4 NEW COKE OVEN DESIGN

There has been little change in the basic coke oven over the last 50 years. In the last decade some new batteries were built in West Germany which differed little from the conventional design except in having wider and taller (2 times) ovens. These new plants are:

Prosper battery, Ruhrkohle AG

Huckingen battery, Mannesmannrohren-Werk AG

Kaiserstuhl III, Ruhrkohle AG

In 1987 The Kaiserstuhl III plant was estimated to cost U.S. \$383 m.⁽¹⁶⁾

By increasing the volume, the number of ovens required for a given annual production rate are reduced. The capital and operating costs and pollution problems are thereby reduced.⁽⁶⁾ Another advantage of the larger ovens is that quality coke can be made from a coal charge containing a higher ratio of non-coking coal than can be used in conventionally sized ovens. For example, the Prosper plant operates on a coal charge containing 58% non-coking and 42% coking coals.⁽¹⁶⁾

The AISI in 1983 concluded that higher ovens will suffer a 40% reduction in effective operating life as they would be more susceptible to wall damage. The European Coking Committee refuted this finding by concluding operating life would not be affected if the ovens were carefully operated and subject to regular and preventative maintenance.⁽⁶⁾

The Germans are considering a new coke oven design that is referred to as the "Jumbo Reactor". Ruhrkohle, Bergbauforschung and several German engineering companies plan a \$33 m pilot plan to aid in the design of a commercial version. Design is targeted to be ready for a 1996 construction decision for a commercial plant.

The concept is essentially a very large conventional oven design but incorporating dry coke quenching, pipeline charging and preheating of coal charge. For a production of 2 mtpy the "Jumbo" compares with typical Japanese and the current largest German batteries as follows: (Table 5.3)

Table 5.3		
	Coke Production Rate tonnes Coke/Oven/24 hr.	Ovens Required
Japanese	32	123
Kaiserstuhl	49	120
Jumbo	160	33

It is claimed the Jumbo Reactor will be able to operate on any type of coal.⁽¹⁶⁾

The following benefits of the Jumbo Reactor compared to a conventional battery design are:⁽¹⁶⁾ (Table 5.4)

Table 5.4	
	Reduction in Cost - %
Coal	10 to 15
Labour	10 to 15
Energy requirement	25 to 35
Pollution Control	40 to 60
Capital cost	0 to 10 (increase)

There is some work going on in both Germany and Japan on totally new cokemaking processes but details are not forthcoming.⁽¹⁶⁾ In Japan a fundamental research effort into the "next generation" of cokemaking is to start (1990) with a 3-year completion date target. The effort is funded by the Iron and Steel Institute of Japan. The Japanese have mentioned that two routes under consideration are: (1) a process that will produce no waste water for disposal and (2) a process that

has only two products, coke and hydrogen.⁽¹⁶⁾

5.5 FORECAST

In the following forecast of the use of non and weak coking coal usage in coke oven blends, the major assumptions are:

- (a) Compared to 16.7% in 1990, by 1995 all Japanese steelmakers will use 20% non-coking in coke oven blends and by 2000 this will have increased to 25% and hold at this level to 2005.
- (b) the rest of the western world will not increase present non-coking coal percentages in oven blends.
- (c) Jumbo reactors for cokemaking will be confined to Germany and represent 4 mtpy coke capacity by 2005 and use 80% non-coking coals.
- (d) Formcoke will not be adopted to any significant degree.

Compared to the amount of coking coal that would have been used if 1990 ratios of non-coking to coking coals in coke oven blends had prevailed, the reduction in coking coal usage is forecast to be: (Table 5.5)

Table 5.5			
Reduction in Coking Coal Consumption - mt			
	1995	2000	2005
Japan	1	3	3
Western World	1	3	8

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6 FUEL INJECTION INTO BLAST FURNACES

6.1 GENERAL

A number of fuels have been injected into blast furnaces for decades to reduce coke consumption. These include coke by-product gases and tars, coke fines, petroleum coke, propane, coal, natural gas and fuel oils. The dominant ones are the last three: coal, natural gas and fuel oils.

6.1.1 Oil Injection

Injection of fuel oil into the blast furnace has been used extensively as a route to minimize coke usage and hence, overall energy cost. Oil use is a function of relative coking coal/oil prices. The Japanese industry commenced oil injection in the early 1960s, dropped the practice for most of the 1980s when oil prices were high and restarted it in 1989. Lower oil prices were part of the incentive to restart. A larger incentive was a coke shortage resulting from a very active steel market.⁽¹⁾

In Japan, to justify fuel oil injection, fuel oil price must be below U.S. \$11 – 12 per barrel or it is more economic to use coke for fuel.⁽¹⁾ The price in August, 1989, when oil injection was restarted, was U.S. \$19 per barrel, reflecting how significant was the shortage of coke.

Figure 6.1 gives the history of oil injection in Japan and its relationship to coke rate. While other factors also affected coke rate over the same period, it is evident that oil injection is an effective way to reduce coke consumption.

The U.S. industry makes wide use of technology: (Table 6.1)

Table 6.1

	Fuel Oil Injection Ratio 1 per thm	Coke Rate kg per thm
1985	16	508
1986	28	507
1987	24	526
1988	20	528
1989	26	522

Dofasco in Canada utilizes fuel oil injection extensively and states it has gone to higher levels than any other steel mill at 150 kg per thm (for a one month period)⁽²⁾, or approximately 165 liters per thm, assuming #4 fuel oil with density of 903 kg/m³.

Hatch and Associates Consultants, Inc.⁽³⁾ concludes that coal injection is favoured over oil injection for a coal price of U.S. \$65 per ton (94% C on an ash free basis) at any oil price over U.S. \$15 per barrel. This ignores capital cost factors.

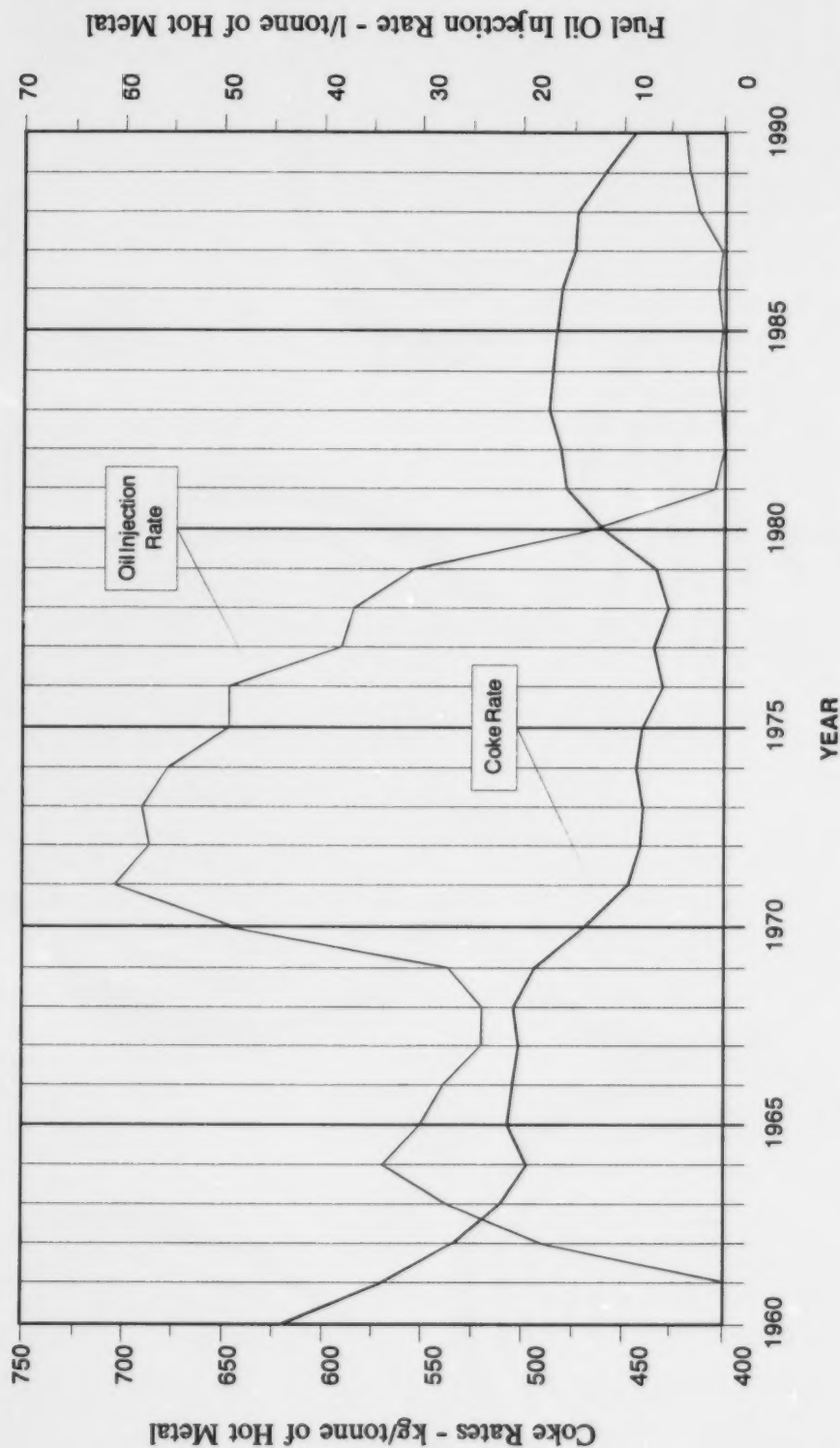
While the capital cost of an oil injection system is lower than that of a system for injecting coal, coal provides a larger impact on the cost of iron production (relative to an all coke operation) than does oil and hence a faster payback period. This is shown by the following figures for Belgium ⁽⁴⁾: (Table 6.2)

Table 6.2

Injectant	Injection Rate kg/thm	Investment for 2 Furnaces U.S.\$ million*	Reduction in Cost of Hot Metal U.S.\$ per t	Payback Period Years
Oil	60	7	0.90	3
Coal	100	29	6.20	1.7
Natural Gas	45 m3/thm	3	(2.00)	—

* Assuming 1 FB = U.S. \$0.0286

Figure 6.1
OIL INJECTION RATES VS. COKE RATES
Japanese Steel Industry



Source: TEX/Coal Manual

The fuel costs used were not provided. Their relative differences would affect the payback period. CANMET⁽⁵⁾ states the limit for oil injection is about 75 kg/thm. Above this level incomplete combustion produces soot emission from the furnace. National Steel⁽⁶⁾ confirms this statement but states soot formation can be overcome by injecting a water/oil emulsion so that the oil droplets explode on injection. A combustion catalyst is also required. Dofasco⁽²⁾ has operated successfully at 150 kg/thm for a month with a coke rate of 375 kg/thm. However, to do so, it had to emulsify the oil and add a combustion catalyst. Dofasco now regularly runs at 70 kg/thm.

Dofasco reports the following effect of oil injection on coke rate: (Table 6.3)

Table 6.3	
Oil Injection Rate kg/thm	Coke Replacement Rate kg coke/kg oil
0 - 20	1.2
20 - 70	1.0
over 70	less than 1.0

With the long term outlook for a faster growth rate in oil prices than those of coal, oil injection will not likely be a significant factor in the future.

6.1.2 Natural Gas Injection

Natural gas is used widely in parts of the U.S. and in USSR for injecting into the blast furnace. Apparently over 90% of the hot metal produced in the USSR utilizes natural gas injection. Natural gas injection in North America is limited to areas in which natural gas is lower cost than fuel oil. For example, Dofasco⁽²⁾ has used gas injection (35 kg/thm) in the past but finds it unattractive at the prices currently prevailing in Hamilton.

Injection levels of natural gas in the U.S. in recent years average: (Table 6.4)

Table 6.4	
Natural Gas Injection Rate kg/thm	
1985	14
1986	25
1987	22
1988	18
1989	24

The main advantage of natural gas over either oil and or coal injection is the low capital investment. As reported in Section 6.1.1, a two furnace installation in Belgium for natural gas cost U.S. \$3 million versus \$7 million for oil and \$29 million for coal injection. National Steel estimates a natural gas installation (2 blast furnaces) would cost U.S. \$0.5 m compared to U.S. \$2 m for oil injection.⁽⁶⁾ The estimate assumes both fuels are available at the plant gate.

National Steel believes the usual injection rate is below 50 kg per thm. Over this level soot and unconsumed hydrogen gas pass through the charge and are wasted. In addition, excessive cooling of the furnace is experienced. Steam injection, usually practised with an all coke operation, can be reduced or eliminated to compensate for the cooling effect of natural gas. However, above 50 kg/thm, oxygen enrichment of the blast air is also required. Research is underway to determine the technical limit of natural gas/oxygen injection.

Steele⁽⁷⁾ has tested simultaneous injection of natural gas and oxygen. Rates as high as 110 kg/thm natural gas with enrichment of blast air to 35% oxygen content were tried. The maximum suitable rate was found to be 75 kg/thm natural gas injection with 27% oxygen content. For every kg/thm natural gas added, 0.85 kg coke/thm were saved.

Warren Consolidated Industries, U.S., has used natural gas injection since 1985 and reports a replacement ratio of 1.4 kg coke per kg natural gas injected.⁽⁸⁾ LTV Steel Company has injected both oil and natural gas at its Cleveland plant. In July 1990 it started a test to remove oil and increase natural gas injection and achieved the following: (Table 6.5)

Table 6.5

Oil Injection kg/thm	Natural Gas kg/thm	Oxygen Enrichment %	Coke Rate kg/thm	Production Hot Metal tpd
55	32	6.0	444	3,968
0	85	8.4	440	4,089
0	96	8.9	405	4,569
0	111	10.2	387	4,575

A side benefit of natural gas injection was a lowering (20%) of the hot metal sulfur content.

Natural gas represents little competition worldwide to coal injection in the future.

6.2 CURRENT STATUS OF PULVERIZED COAL INJECTION (PCI)

Coal injection into blast furnaces was tested in France in 1840. Apart from some unsuccessful attempts at pneumatic injection of coal between 1910 and 1920 and experiments in the USSR in the early 1950s, it was not until the early 1960s that coal injection was successfully practised by Arco Steel in the U.S. and Shoudu Iron and Steel Co. in China.

In the late 1970s, with the coming of the second oil price escalation, coal injection was given serious consideration, primarily in Europe and Japan. PCI systems were installed in Europe (France) in 1982 and in Japan in 1981.

Table 6.6 summarizes the situation in the western world as it existed in 1987. In total, 47 blast furnaces were equipped with PCI and a further 17 were to receive the PCI system in 1988 and 1989. Installations were primarily in northern Europe, 47%, and Japan, 43%. The remaining 10% were in Italy, South Korea, Taiwan, Brazil and U.S.A.

The table ignores the eastern block nations. By 1987 PCI was well established in China where injection of anthracite was, and still is, used extensively.

In 1987 the average injection rate was 85 kg per tonne hot metal (thm) with the maximum being 140 kg/thm (by Thyssen in Germany). The lowest coke rate was at 295 kg/thm (also by Thyssen).

The type of coals used in 1987 were: (Table 6.7)

Table 6.7

Type	Number of Furnaces	%
Steam	20	42
Steam/anthracite/pet coke/ charcoal/low volatile thermal	15	32
Non-coking		74
Steam/coking	5	11
Weak coke	5	11
Coking	2	4
	47	100

The only true coking coals used were by Krupp in Germany. Any weak coking coal consumed was in Japan and South Korea. In Japan 78% of the furnaces used steam coal; 22% weak coking coals.

There are a number of named processes for grinding, distributing and injecting coal (e.g. Macawber-British Steel, Kawasaki, Armco-Babcock and Wilcox). Both mechanical and pneumatic systems are used⁽⁹⁾. A major concern is the explosion hazard of suspended fine coal particles. Air-proof systems operating under vacuum conditions plus control of oxygen concentration minimize the danger. Pulverized fine coal (80% minus 0.075 mm) presents more of an explosion hazard than does granulated coal (95% minus 2 mm) used by British Steel.

Moisture content of the ground coal must be controlled below 3% or "balling" of the coal into lumps occurs and the injection system plugs. In practice, moisture contents of about 1% are generally employed.

Table 6.6

Pulverized Coal Injection in Western World (1987)

County	Company	Blast Furnaces with PCI		1987		1987 Minimum	Type	Coal Used		
		Operating In 1987	To Start in 1988-89	Coal injection Rate kg/thm ⁽¹⁾	(Max.)	(Ave.)		Rate kg/thm	VM %	Ash %
Europe										
Belgium	Sidmar	2		110	100	307	Steam	23-35	9-14	
France	Sollac	3	2	100	95	333	Low vol.	11	13	
	HFRSW	1	1	80	80	395	High vol.	33	7	
Germany	Thyssen	4	1	140	120	295	Anthracite to High vol.	9-35	6-14	
	Dillinger	2	1	100	95	363	High vol.	39	7	
	Krupp	2		100	100	390	Coking	22-23	7	
Italy	Deltasider	1		60	60	440	Low vol.	18	6	
Netherlands	Hoogovens	2		120	120	370	Steam/coking	17-37	3-9	
Spain	Ensider Altos Hornos		2 1				Domestic Domestic			
Sweden	SSAB	3		100	95	354	Pet.coke/ med.& high vol.	12-40	0.4-10	
U.K.	British Steel	3	4	92	90	375	Coking/non- coking	23-39	3-12	
	Sub-total	23	12	140	99	295				
Asia										
Japan	Godo	1		59	59	435	Steam	30-35	9-11	
	Kawasaki	1		16	16	471	Steam	23-37	8-12	
	Kobe	2	1	117	95	381	Weak coking	30	10	
	Nakayama	2		96	87	368	Steam/pet. coke	22-26	8-9	
	Nisshin	2		70	65	395	Steam	32-37	8-12	
	NKK	1		67	67	400	Steam	32-34	7-10	
	NSC	7		81	65	392	Steam	26-36	7-11	
	Sumitomo	2		87	65	405	Weak coking	25-36	7-11	
S. Korea	Posco	1	3	65	65	398	Weak coking	33-38	7-10	
Taiwan	China Steel	1	1	35	35	448	High vol.	30-35	7-9	
	Sub-total	20	5	117	66	368				
Americas										
Brazil	Acesita	2		100	100	395	Charcoal	23	6	
U.S.A.	Armco	2		90	90	390	Med/high vol.	23-35	3-12	
	Sub-total	4		100	95	390				
	Total	47	17	140	85	295				

(1) kg coal injected per tonne hot metal produced.

Source: Coal Injection into the Blast Furnace, D.S. Gathergood,
British Steel Corp., Paper given to IISI Technical Exchange
Session, Brussels, April, 1988.

6.3 RATIONALE FOR ADOPTION OF PCI

The principal reason for the wide adoption of PCI in the 1980s was to reduce the cost of reductant. Lower cost carbon (steam coals, petroleum coke, coke fines, anthracite, weak coking coals, chars) could be used to replace coke and hence high cost coking coals.

In the 1990s an equally important reason will be to extend the operating lives of aging coke batteries and/or to permit closure of some cokemaking capacity without affecting hot metal production.

Ignoring the possibility that new coke batteries may not be able to meet tightening air emission standards, a PCI unit is still favoured over a new coke battery because it is much cheaper to build and provides operating cost savings.

6.3.1 Capital Cost

CANMET⁽⁹⁾ in 1987 estimated the cost of a 175,000 tpy PCI system at: (Table 6.8)

Table 6.8	
	U.S. \$ million
Raw coal storage handling	1.2
Grinding	5.0
Furnace injection system	4.0
Auxiliaries	2.5
Controls	2.3
	15.0

Papers presented April, 1988 at IISI Technical Exchange Session gave the cost of a granulated coal injection system based on British Steel's experience as U.S. \$23 – 38 million and of a PCI system at Sidmar in Belgium at U.S. \$29 million (2 blast furnace operations with a coal injection rate of 100 kg/thm (tonne of hot metal) produced. The British Steel plant compared with U.S. \$113 million for a new coke battery.

This study was provided current approximate capital costs for a PCI system shown Table 6.9.

6.3.2 Operating Cost Savings

PCI not only replaces higher cost coke with lower cost coal, but it also increases blast furnace productivity. Productivity improvements result because of:

- Minimization of inactive zones in the lower part of the furnace.
- Smooth burden descent with fewer slips and hang-up.
- Lower and stable silicon assays in hot metal product.
- More stable furnace operation.

Depending on the type of coal used and specific furnace operating parameters, one tonne of coal injected displaces 1 to 1.2 tonne coke. A conservative assumption is one tonne coke per tonne PCI.

Sidmar in Belgium reported in 1988⁽⁴⁾ that at a PCI rate of 100 kg/thm the reduction in cost of making pig iron was U.S. \$6.20 (FB 218 per t; 1FB = U.S. \$0.0286) per tonne resulting in a 1.7 years payback period for U.S. \$29 m investment.

Table 6.9					
Current Approximate Capital Costs for a PCI System					
	Injection Rate kg/thm	Coal Volume tpy	Capital Cost		
			Number of Blast Furnaces	U.S. \$ per annual tonne	Million \$ U.S.
National Steel	150	400,000		75	30
Stelco	150	350,000	2	100	35
Westar				45 – 75	
Hatch	200		2		100*

* Includes an oxygen plant

Pohang Iron and Steel Co. ⁽¹⁰⁾ reports a 7% reduction in costs with PCI (100 kg/thm) compared to an all coke operation. This overall reduction was composed of the following: (Table 6.10)

Table 6.10	
Item	% Reduction
Coal cost	9
Operating cost:	
Coal preparation	8
Blast furnace operation	1
By-product credit	(8)
Fixed costs	4
Overall	7

British Steel Corp states that payback periods of 18 to 30 months have been realized on PCI installations ranging from U.S. \$60 – \$100 million in capital cost.⁽⁷⁾

CANMET ⁽⁹⁾ using Armco data calculates savings with PCI of U.S. \$5.68 per thm if compared to an all coke operation. If PCI replaced fuel oil injection, the savings are U.S. \$10.18 per thm. These savings assume a coke price of U.S. \$120 per t, coal price of U.S. \$60 per ton, oil price of U.S. \$230 per t, a coke rate of 500 kg/thm with no injection and replacement ratios of 1.04 kg coke per kg coal and 0.83 kg oil per kg coal.

6.4 MAXIMUM PCI RATE

Injection of any auxiliary fuel into the blast furnace causes a temperature drop. Unless the fuel is preheated, it must be brought up to furnace temperature by absorbing heat from the contents of the blast furnace. More importantly, the gasification/reforming of the fuel to the reactive gases, carbon monoxide and hydrogen, is endothermic, therefore further cooling the furnace.

In conventional blast furnace operation steam is injected with the blast air. The added moisture is beneficial in aiding downward movement of the coke/iron ore/flux charge without "hang-ups" and sudden slumps. However, steam injection cools the blast furnace. The physical benefits of steam injection can also be achieved by injecting fuels into the blast air. Consequently the

temperature drops resulting from fuel injection can be compensated for by reducing or eliminating steam injection. At some level of coal injection, however, injecting more coal will produce more cooling than can be compensated for by cutting steam injection. If auxiliary heating is not supplied, the productivity of the blast furnace will start to decline. In practice, auxiliary heating can be achieved by adding oxygen to the blast air thereby creating a hotter flame (less nitrogen injected) and/or by preheating the incoming blast air to higher temperatures. Oxygen injection is quite widely used. In France, plasma torches are employed on several blast furnaces to superheat blast air but this can only be justified where electricity prices are low (say below U.S. 3¢ per kWh) ⁽³⁾.

Table 6.11 summarizes the impacts on blast temperature and coke usage of injecting various materials into a blast furnace.

Table 6.11 shows that steam injection lowers the temperature and necessitates a higher coke consumption to produce the same amount of hot metal. Preheating the blast air decreases coke consumption as does the addition of oxygen to the blast air. Coal has significantly less impact on temperature than does oil or natural gas. Similarly, coal reduces coke consumption more than the other two fuels. Anthracite is more effective than high volatile coals indicating the lower the hydrogen to carbon ratio in the fuel, the lower the temperature drop and the higher the reduction in coke consumption.

Table 6.12 summarizing PCI installations at western world blast furnaces in 1987, indicated for those blast furnaces equipped with PCI systems, the average coal injection rate was 47 kg per thm. There has been considerable progress in the interval. This is shown in Table 6.12.

While Westar Mining's information in Table 6.12 indicates the total western world steel industry uses an average of 38 kg per thm, blast furnaces in Japan and South Korea run consistently now at 65 – 100 kg PCI per thm. Injection rates in the 170 – 180 kg per thm metal have been maintained for significant periods in commercial blast furnaces.

Table 6.11
Effect on Blast Furnace Temperature and Coke Usage
of Various Materials Injection⁽¹⁾

Injectant	Quantity	Change in Flame Temperature °C	Change in Coke Usage kg/thm
Steam	10 g per m ³ blast air	-58	+7.7
Oxygen	1 % enrichment of blast air	+54	-1.4
Preheating blast air		+83	-15.4
Anthracite	100 kg/thm	-162	-91.0
High vol steam coal	100 kg/thm	-218	-76.1
Heavy fuel oil	100 kg/thm	-321	-98.4
Natural gas	100 kg/thm*	-513	-82.6

* 132 m³ per thm.

All sources stated that the maximum PCI rate technical limit has yet to be established. Without oxygen injection, rates in the 150 – 200 kg per thm seem achievable. If oxygen injection is practised, several sources are of the opinion that the achievable limit may approximate 300 kg per thm (60% coke replacement). British Steel, Hoogovens and ILVA plan major test work at British Steel's Cleveland Works to determine the actual technical limit of PCI. They plan to work up to rates as high as 485 kg per thm. At this level, British Steel estimates the following oxygen and coke rates will be required and by-product credits will result: (Table 6.13)

	Coke only Operation	PCI Operation
PCI rate – kg/thm	Nil	485.5
Coke ratio – kg/thm	489.5	109.2
Coking coal consumption for coke manufacture – kg/thm	741.5	165.3
By-product production – kg/thm		
Tar	29.7	6.6
Benzole	9.7	2.1
Coke fines	80.2	17.7
Energy in off-gases – GJ	8.63	7.35

FOOTNOTES TO TABLE 6.12

- (1) T. Okada, Kobe Steel, U.S./Japan Coal Conference, June 6, 1990, Hawaii
- (2) Supply and Demand for Coking Coal in the Japanese Steel Industry, Sohei Nabeshima, Nisshin Steel Co. Canada/ Japan Coal Conference, May 13 – 15, 1991, Halifax.
- (3) Blast furnaces using PCI only, not average for Japanese total industry.
- (4) Market Force Impact on Coal Demand, T. Tanaka, Nippon Steel Corp., Australia/ Japan Coal Conference, April, 1990, Australia.
- (5) High Coal Injection Rate Operation in Kobe #3 Blast Furnace, Y. Yoshadia, Kobe Steel, 50th Ironmaking/74th Steelmaking Conference, Washington, D.C., April, 1991.
- (6) Interview of Mr. Tanaka, NKK Corp., Brisbane Courier-Mail, May 4, 1990.
- (7) Strategic Study of Future Ironmaking Processes, D.W.R. George, Stelco Technical Services Limited, study for Canada

Table 6.12
Present Status of PCI and Forecasts
PCI Level (kg/thm)

Organization	Date	Present Typical	Highest To Date	Technical Limit	Plans or Forecast kg/thm
Japan					
Kobe Steel	June, 1990 ⁽¹⁾	100 (Kobe)	160 ⁽³⁾		Plan 150 in near future and eventually 200
Nisshin Steel	May, 1991 ⁽²⁾	80 (Japan) ⁽³⁾	170		Plan 200 in near future
Nippon Steel	April, 1990 ⁽⁴⁾	65 (NSC)		150 no O ₂ 200 with O ₂	Plan 150
NKK	May, 1990 ⁽⁶⁾	65 (NKK)		350 ⁽⁸⁾	Plan 150 in near future; testing 250-300 using O ₂ injection ⁽⁷⁾
Other					
British Steel	April, 1991 ⁽⁹⁾		180 consistently 220 for several weeks 260 for short periods		Plan tests up to 400 in joint venture with Hoogovens and ILVA at Cleveland works of BSC
	May, April, 1988 ⁽³⁾				200 practical now
BHP/Utah	May, 1991 ⁽¹⁰⁾			250 ⁽¹¹⁾	
Canmet	May, 1991 ⁽¹⁰⁾			Approx. 300	
Hatch & Assoc.	May, 1991 ⁽¹⁰⁾		200 ⁽¹⁴⁾	Approx. 300	
National Steel	May, 1991 ⁽¹⁰⁾			Approx. 300 170-200 no O ₂	By 2000 all large blast furnaces will be equipped with PCI
Pohang Steel	April, 1991 ⁽¹²⁾	100			Plan substantial increases
Shoudu (China)	1966 ⁽¹³⁾		279(anthracite)		
Thyssen(German)	1987 ⁽¹³⁾		177		
Westar	May, 1991 ⁽¹⁰⁾	38(western world)		200 practical 225 possible	Western world: 1996=80; 2000=120
Callide					
Coalfields	Oct, 1990 ⁽¹⁵⁾	67-75(Japan)	150(Japan)		Japan: 110-120 in few years and eventually to 120-130 ⁽¹⁶⁾
Institute of Energy Economics	Oct, 1990 ⁽¹⁶⁾			350	
USBM	May, 1991 ⁽¹⁰⁾			125-150 practical	US: 1995=50
Coal and Allied	July, 1990				Western world: 100 practical potential

Department of Energy, Mines and Resources, September 28, 1990.

- (8) Future of the Japanese Steel Industry and a Suggestion to the Canadian Coal Industry, Minoru Hashimoto, NKK Corp., Canada Coal Conference, Victoria, May, 1989.
- (9) Towards 300 kg per thm Coke Rate with Granular Coal, G. Hanniker, British Steel Corp. PLC, 50th Ironmaking/74th Steelmaking Conference, Washington, D.C., April, 1991.
- (10) Interview during this study.
- (11) Assuming worldwide average coke rate is 500 kg/thm and half is replaced.
- (12) Pulverized Coal Injection at Kwangyong Works, J.S. Noh, Pohang Iron and Steel Co. Ltd. 50th Ironmaking/74th Steelmaking Conference, Washington, D.C., April, 1991.
- (13) Coal Injection into the Blast Furnace, D.S. Gathergood, British Steel Corp., IISI Technical Exchange Session, April, 1988.
- (14) At Bethlehem Steel's Burns Harbour Plant where two blast furnaces are being tested with PCI using O₂ injection (U.S. \$100 million installation).
- (15) Changing Technologies in the Steel Industry and the Likely Effect on Coking

Coal during the 1990s, I. McCauly, Collide Coalfields Pty. Ltd., Australia/Japan Coal Conference, October, 1990.

- (16) The level at which the blast furnaces can operate at peak energy efficiency.

6.5 MINIMUM COKE RATE

The technical limit on how much pulverized coal can be injected into a blast furnace will be dictated by the minimum amount of coke required to support the iron ore and flux charge while still providing bed porosity. The porosity is necessary for upward movement of gases and downward movement of molten iron and slag.

Table 6.14 demonstrates how coke rates have declined in major steel producing areas since the mid-1950s and indicates that current coke rates in industrialized nations are in the 450 – 525 range. The U.S.A., with little use of PCI, is at the high end of the range, while Europe and Japan, where PCI is widely used, are at the lower end. Direct comparisons are difficult to make as oil and/or natural gas injection is used to varying degrees, thereby masking somewhat the impact of PCI.

The industry has yet to establish the minimum coke rate that will allow consistent stability of operation.

Shoudu in China in 1966 and Dunkirk in 1985, both achieved coke rates of 333 kg/thm. Thyssen in 1987 operated well at a coke rate of 295

Table 6.14
Coke Rate (kg coke consumed in blast furnaces
per tonne hot metal or pig iron produced)

CY	Europe						USA	Japan	Canada
	United Kingdom	France	West Germany	Average W.Europe	USSR	Average E.Europe			
1956	986	1,029	949						
1957					817		842	718	859
1960	825	972	834		724		749	619	769
1965	680	784	672	737	586	832	650	507	585
1970	625	626	559	681	575	651	630	478	544
1975	609	532	498	662	547	600	612	444	491
1980	588	521	515				569	450	
1985	544	507	531				508	485	430
1987	484	472	459				526	477	449
1989							522	460	446

kg/thm, apparently the lowest rate achieved in a commercial blast furnace without addition of scrap iron.⁽¹¹⁾

Using plasma preheating of blast air, coke rates as low as 150 kg per thm have been achieved in France on a commercial furnace⁽⁷⁾. On pilot plant tests coke rates as low as 105 kg/thm have been achieved while still maintaining good bed permeability.⁽¹¹⁾ This rate resulted from injecting 400 kg coal/thm.

Dofasco⁽²⁾ and USBM⁽¹²⁾ both expressed the opinion that coke rates of 300 kg per thm should be readily achievable. Assuming a typical coke rate of 500 kg/thm with no fuel injection, a coke rate of 300 kg/thm is equivalent to a PCI rate of approximately 200 kg per thm. Consequently, a replacement of approximately 40% of the coke used in steelmaking should be readily achievable.

6.6 TYPES OF COAL USED

For PCI the industry has tended to employ high volatile steam and weak coking coals, both considerably lower cost than coking coal. Not only are high volatile coals cheaper, they also have better combustion characteristics.

No technical restrictions have been found on the type of coals that can be used. Ranks from lignite to anthracite (with volatile matter and ash contents ranging from 5 to 50% and 3 to 18%, respectively) have proven acceptable. Pohang⁽¹⁰⁾ has successfully used 11 different coals ranging from 25 – 39% VM and 7 – 10% ash.

As PCI rates increase, there is a body of opinion that believes the trend will be towards low volatile coals. At high injection rates, high volatile coals tend to cause soot problems. Low volatile coals do not present this problem and also have more "reducing power" per tonne, i.e., more fixed carbon.⁽¹³⁾

Low ash content will become increasingly important as PCI rates increase. The ash must be eliminated from the blast furnace as slag which increases the cost of fluxing agents. The assay of the ash will also be important. Low alkali metal contents will be desirable. CANMET believes coal with ash content below 10% and with low alkali assays will be required. In addition, coals should have low inherent moisture contents, be easy to grind, yield low amounts of tar on combustion and contain low phosphorus levels.⁽⁹⁾

Some believe the best coal for high PCI rates will prove to be a mixture of anthracite and high volatile coal, the latter for better combustion; the former, for "reducing power".

It is possible that ways can be found to overcome the soot formation problem of high volatile bituminous coals. There is some indication that adding lime or iron oxide to the coal may alleviate this problem.

Considerable research is required to define the optimum coal. CANMET⁽⁵⁾ has initiated a major study to establish important characteristics of coal for PCI use and to test Canadian coals for suitability.

The Japanese steelmills, the major purchasers of PCI coal, state the major criterion determining their choice of coal is, and will continue to be, price. NKK in 1989⁽¹⁴⁾ stated that the drive to high PCI rates will mean Japan's purchases of weak-coking coals will increase because these coals are significantly lower in cost than coking coals. Nippon Steel stated in 1990⁽¹⁵⁾ "there are two reasons we intend to raise the (PCI) ratio; the first one is to use lower priced inferior coals and the second one is to extend the life span of coke ovens by lowering the operational level down to a more adequate level and thus reduce the burden on the coke ovens".

The USBM does not think coking coals will be used for PCI.⁽¹²⁾

It is possible that the price differential between steam and coking coals could erode should coking coal prices stagnate and steam coal prices increase because of strong demand. Thereby at some point the use of coking coals might become economic. Should the inroads PCI will make on coking coal demand result in decline of price, the differential between coking and steam coals will disappear more quickly. The question then becomes one of whether or not western Canadian coking coal mines can survive at the lower price.

Increasing PCI rates would impact on coking coals in a second way. As coke rates decline, some experts think that the remaining coke will have to be of better quality than is now produced. Not only will there be less coke per unit of iron ore charged, but it will have to stand up for a longer time in the furnace or bed permeability will be affected. At a PCI rate of 200 – 250 kg/thm, for

example, coke will have twice the residence time in the furnace.⁽¹⁶⁾ Bethlehem Steel reportedly believes coke strength will have to be increased.

To achieve the stronger coke that will be required, it is argued better coking coals will have to be used to provide increased hot strength values (CSR index*). This will force the removal of U.S. low, medium and some high volatile coals from the Japanese blend as they contribute to low CSR values. In addition, these coals expand during coking causing oven wall damage and high maintenance costs in coke batteries. As a result, B.C. and Australia coking coals should benefit.

Some industry experts are of the opposite opinion. They believe present coke will be adequate. British Steel and Thyssen reportedly are of this opinion.^{(2) (16)} One theory states that with high PCI rates the coke strength does not have to be as high as at present⁽⁹⁾ because of less solution loss of coke. The coke lumps, therefore, are weakened and degraded at a slower rate.

There is operating experience⁽¹⁷⁾ that some physical changes in blast furnace operation (such as the location of the injection lances, the distribution pattern of the coke in the furnace, the thickness of the iron ore bed) can eliminate or alleviate problems experienced at high PCI rates without the quality of the coke having to be changed.

Considerable research will have to be done to resolve this question of the quality of coke required at high PCI rates.

6.7 FORECAST OF IMPACT OF PCI ON COKING COAL DEMAND

All people interviewed in the study are of the opinion that both PCI injection rates per furnace and the number of furnaces employing the system will grow. These opinions are also consistent with published statements of steel companies.

An indication of the acceptance of the PCI concept was its integration into the basic design of the new Pohang steelmill in South Korea, the latest conventional integrated steel plant built and, some think, the last.

The adoption of PCI technology will not be at a uniform rate worldwide. For example, Canadian steelmills have no intention of installing PCI. CRU Ltd.⁽¹⁶⁾ forecasts by 1995 that the following percentages of blast furnaces will be equipped with PCI systems: (Table 6.15)

Table 6.15	
	%
Japan	80
Europe	75
North America	50
South Korea	50
Latin America	30

The USBM⁽¹⁸⁾ forecasts by 1995 that 40% of U.S. hot metal production of 45 – 47 mt will be made using PCI thereby replacing 25% of the coke that would otherwise have been used. This represents a 10% reduction in total coke consumption by the U.S. steel industry or a 13% reduction in coking coal consumption.

Several Canadian and Australia coal producers in 1990 commissioned a study of PCI and its impact. Based on this study, the current PCI rate for the western world of 38 kg/thm will grow to 80 in 1996 and 120 in 2000. The data presented earlier in Table 6.12 indicates that such a forecast seems reasonable.

Table 6.12 also indicates that a realistic eventual PCI rate might be 300 kg per thm. If it is assumed the above forecast holds to 2000 and that 60% of the western world steel mills in 2005 will be operating at a PCI rate of 300 kg per thm (i.e. an average rate of 175 kg/thm), the impact of PCI on coking coal demand might approximate that shown in Table 6.16. One would expect a much faster growth rate in Japan. An average rate of 150 kg per thm by 1995 growing to 200 by 2000 and 300 by 2005 may be more realistic. This impact on coking coal demand by Japan is also shown in Table 6.16.

* coke strength after reaction

Table 6.16

Forecast of the Impact of PCI on Coking Coal Demand

	Million tonnes			
	1989	1995	2000	2005
Japan				
Crude steel production	108	95	88	88
Blast furnace hot metal	75	65	57	57
Coking coal required with 1989 coke rate ⁽¹⁾	52	45	39	39
Forecast PCI rate - kg/thm		150	200	300
Coking coal required ⁽²⁾		30	22	14
Reduced coking coal requirement				
mt		15	17	25
%		33	44	64
Western World				
Crude steel production	497	500	510	550
Blast furnace hot metal	338	315	255	265
Coking coal required with 1989 coke rate ⁽³⁾	254	236	191	199
Forecast PCI rate - kg/thm		80	120	175
Coking coal required ⁽²⁾		198	145	130
Reduced coking coal requirement				
mt		38	46	69
%		16	24	35

(1) Assuming 460 kg/thm and 1.5 kg coal/kg coke.

(2) Assuming 1 t PCI replaces 1 t coke.

(3) Assuming 500 kg/thm and 1.5 kg coal/kg coke.

REFERENCES TO SECTION 6

- (1) Tex Coal Manual, 1990
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- (3) An Evaluation of thermal Plasma Energy to Heat Blast air for Iron Production, CMP Report #89-1, Hatch Associates Consultants, Study for Center for Metals Production, June, 1989.
- (4) Pulverized Coal Injection at Sidmar, A Hamilius, IISI, Technical Exchange Session, Brussels, April, 1988.
- (5) Interview J.F. Gransden, CANMET, during this study.
- (6) Interview J.A. Rainis, K.P. Hass, National Steel Corp., during this study.
- (7) Strategic Study of Future Ironmaking Processes, D.W.R. George, Stelco Technical Services Limited for Canada Department of Energy, Mines and Resources, September 28, 1990.
- (8) Natural Gas Injection at W-1 Blast Furnace, W.G. Sherwood 50th Ironmaking/74th Steelmaking Conference, Washington, D.C., April, 1991.
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- (10) Pulverized Coal Injection at Kwangyang Works, J.S. Noh, Pohang Iron and Steel, 50th Ironmaking/74th Steelmaking Conference, Washington, D.C., April, 1991.
- (11) Coal Injection into the blast Furnace, D.S. Gathergood, British Steel, IISI Technical Exchange Session, April, 1988.
- (12) Interview R. Brown, USBM, during this study.
- (13) Interview G.D. Lill, BHP-Utah, during this study.
- (14) Future of the Japanese Steel Industry and a Suggestion to the Canadian Coal Industry, M. Hashimoto, NKK Corp. Canadian Coal Conference, Victoria, May, 1989.
- (15) Market Force Impact on Demand, K. Tanaka, Nippon Steel Corp., Australia-Japan Coal Conference, April, 1990.
- (16) Status of Pulverized Coal Injection, P. Simon, CRU Ltd., U.K., Coal Transportation Conference Proceedings, May, 1991.
- (17) High Coal Injection Rate Operation in Kobe #3 Blast Furnace, Y. Yoshida, Kobe Steel, 50th Ironmaking/74th Steelmaking Conference, Washington, D.C., April, 1991.
- (18) Interview T. Peters, USBM, during this study.

7 NEXT GENERATION STEELMAKING PROCESS

7.1 GENERAL

There has been sporadic effort by the world's steel industry over the last two decades to develop a new steelmaking process that will replace the present coke-battery, blast furnace route. In the last few years these efforts have been accelerated.

Some 20 processes have been developed and tested to various degrees over the years. Seventeen of these are listed in Table 7.1. Another five Japanese processes are not shown as these have been incorporated into the DIOS joint venture project or dropped.

Three processes involve the direct use of coal to reduce iron ore to hot metal in a single vessel. In the others a preliminary step is used to reduce the iron ore to either wustite (FeO containing 75 – 80% Fe) or direct reduced iron (DRI, 90–95% Fe). These prereduced iron forms are then either reduced (FeO) or melted (DRI) to produce hot metal in a second vessel to which coal is added and gasified. The reducing gases produced from coal in the second vessel are used in the prereduction first stage.

In 9 of the 17 processes listed in the table, the energy to melt the DRI or to reduce FeO in stage 2 is supplied by electricity. The other processes use coal as both the reductant and the source of heat.

The ideal steelmaking process should:

- (i) Eliminate the high cost (capital, operating and maintenance) unit operations of cokemaking, and iron ore pelletizing.
- (ii) Eliminate the pollution problems of cokemaking.
- (iii) Utilize run-of-mine iron ore or fine iron concentrates and not require pelletized or lump material.

- (iv) Utilize any source of low cost carbon, e.g., thermal and steam coals, anthracite, coke fines, char, instead of high cost coking coals.
- (v) Have good economics at low design rates (e.g., 0.5 – 1.0 mtpy versus 2.5 – 3 mtpy for the present integrated operation).
- (vi) Be able to be started up and shut down easily in response to market demands.
- (vii) Have shorter reaction times for reducing oxide to metal than the present system.

7.2 MAJOR CONTENDERS

Four processes listed in Table 7.1 are believed by their promoters to meet most of these criteria and major development programs have been initiated or just been completed. These processes are:

- (i) Corex (South Africa)
- (ii) HIs melt (Australia)
- (iii) DOIS (Japan)
- (iv) AISI (USA)

(i) Corex

The Corex process is the only one of the new generation of processes that is commercial. In 1985, ISCOR ordered a 300,000 tpy plant for construction at its steel plant in Pretoria, South Africa. The plant started operating August 19, 1988 and was completely taken over by ISOR and integrated into the production line of Pretoria Works on December 23, 1989. A second Corex plant has been ordered for South Africa as well as another for India.

The process is owned and marketed by its developers, Deutsche Voest-Alpine Industrieanlagenbau (Germany) and Voest-Alpine Industrieanlagenbau (Austria).

The process is carried out in two stages. Stage 1 consists of a shaft furnace to the top of which lump or pelletized ore is added. Reducing gas from Stage 2 converts the iron ore to DRI which falls into a fluidized belt melter-gasifier, Stage 2. Coal is added to Stage 2 along with oxygen. Combustion of the coal produces the heat for the process and generates the reducing gases used in Stage 1. Molten metal and slag are tapped from Stage 2.

The Corex process has several disadvantages that the other new processes do not seem to have. It must have a market for by-product heat and has high capital cost per unit of hot metal produced.

(ii) HIs melt

In 1981 CRA Ltd. (Australia) and Klockner Stahlforschung (Germany) started a joint venture to develop a steel making process involving coal and iron ore injection into a molten bath of iron. The approach chosen capitalized on Klockner's experience with injecting solids into liquid steel. In 1984 a 30,000 tpy pilot plant was constructed at Klockner's operations in Germany. In 1987 Klockner withdrew from the project and in 1989 Midrex Corp., (a subsidiary of Kobe Steel) entered a 50% ownership arrangement with CRA.

In June, 1990 the pilot plant work was completed. CRA and Midrex have now decided to construct a U.S. \$100 million, 100,000 tpy demonstration facility in Australia. Construction is to begin in the second half of 1991 and start-up the end of 1992. To date \$100 million has been spent on the process. The target completion date for successful demonstration of technical and economic feasibility is 1995. The HIs melt process differs from the other four processes in that it uses iron ore fines with no pretreatment other than preheating.

(iii) DIOS

In 1984 the U.S. \$87 million DIOS (Direct Iron-Ore Smelting Reduction Process) project was initiated by a consortium of eight Japanese steel mills with some funding from the Japanese government (MITI). For the first three years research was undertaken on various components of the process. This was followed by a 200,000 tpy demonstration plant (now under construction). A pre-feasibility study based on the results is to

follow and finally a conceptual design for a commercial plant is to be completed in 1994.

The ultimate aim of the project is to develop a process to replace coke oven-blast furnace technology at production levels in the 3.5 million tpy range.

The DIOS process includes technology developed by a number of the consortium members but is basically the NKK process. In the first stage, fine ore is prereduced to FeO in a fluidized bed. The FeO produced is then injected along with coal and oxygen directly into a molten iron bath in Stage 2. The reducing gases made in Stage 2 pass to Stage 1 to reduce iron ore to FeO.

(iv) AISI Project

In May, 1989 the U.S. Department of Energy (DOE) and the American Iron and Steel Institute (AISI) signed an agreement to construct and operate a pilot plant at Monroeville, Pennsylvania. The objective is to develop a direct steel-making process that will reduce pelletized iron ore with non-coking coal to liquid steel in a continuous process. The project is forecast to cost U.S. \$46 million, split 77% DOE and 23% AISI, and take four years.

A pilot plant was completed in June, 1990. The target is to complete the pilot plant program by the end of 1991. A feasibility study based on the results will then be undertaken. Concurrent supportive basic programs at several universities are also underway as part of the project. The process involves the reduction of iron ore to FeO in Stage 1, followed by reduction of the resulting FeO in a second stage. Reduction to metal is accomplished by injection of FeO from Stage 1, fluxes, coal and oxygen into a bath of molten iron in Stage 2. The reducing gases produced in Stage 2 are used in Stage 1 to produce FeO. The process is similar to DIOS except the use of pelletized ore permits the fluidized bed used in DIOS to be replaced by a simpler pre-reduction design unit.

The AISI is the least well developed of the four processes under consideration.

7.3 DEMONSTRATED BENEFITS

Only the Corex process is considered to be commercially proven and as such publishes realistic economic data.

At the rate of 1 mtpy hot metal, the Corex process (2 Corex modules of 0.6 mtpy each) is calculated⁽¹⁾ to reduce the cost of hot metal by approximately 30% compared to the conventional coke/blast furnace route. This translates to a net savings of approximately U.S. \$65 per tonne steel, assuming by-product gases can be sold and the cost of processing hot metal to steel is the same.

The capital and operating costs (1 mtpy hot metal) of Corex and coke/blast furnace plants compare as follows:

(i) **Capital Cost (U.S. \$ per annual tonne hot metal)**

	<u>Corex</u>	<u>Coke/ Blast Furnace</u>
Corex Plant	165	Coke Ovens 125
Oxygen Plant	<u>35</u>	Blast Furnace <u>170</u>
	200	295

(ii) **Operating Cost (U.S. \$ per tonne hot metal)**

	<u>Corex</u>	<u>Coke/ Blast Furnace</u>	<u>Difference</u>
Operating Cost*	95	135	40
Financing (10%, 15 years)	<u>45</u> 140	<u>70</u> 205	<u>25</u> 65
Gas Credit**	<u>25</u> 165	<u>15</u> 220	<u>(10)</u> 55

The Corex operating costs are sensitive to coal and iron ore costs. The cost of hot metal changes by approximately U.S. \$6 per tonne for a U.S. \$10 change in coal price and U.S. \$14 for a U.S. \$10 change in ore price.

Using costs at a production rate of 1 million tpy hot metal, biases the comparison towards the Corex process. At this rate, Corex units would be operating at optimum levels. However, even at a 3 mtpy rate, the optimum for

coke/blast furnace plants, Corex reports better costs than the conventional process.

The Corex process produces a large excess of by-product fuel gas which must be sold. An option is to generate electrical power. This, however, necessitates more capital.

The Corex process is probably going to be used to fill the gap until one of the HIs melt/AISI/DIOS type processes is proven. As a company is forced to close some cokemaking capacity, hot metal made by the Corex route could permit the company to run its existing blast furnace(s) at capacity. Similarly, the hot metal from a Corex plant could be used to dissolve scrap as feed to a BOF and allow an old blast furnace to be closed.⁽²⁾

The fact that the Corex process is economic at rates as low as 300,000 tpy, make it a contender for generating steel in areas with small local markets.

7.4 TYPES OF COAL REQUIRED

The main incentive for the new processes is to divorce the making of steel from coke and the pollution problems associated with cokemaking. A second important incentive is to enable steel to be made with lower cost coals.

The Corex process works well with coals up to 25% ash and 35% volatile matter. Coals with higher ash can be used but only if the volatile matter is lower, e.g., 32% ash, 30% volatile matter. Similarly, higher volatile coals can be used with lower ash contents, e.g., 38% volatile matter, 5% ash. The process has run with coals ranking from anthracite to lignite. However, the lower volatile coals are superior. High volatile coals are best mixed with low volatile material, e.g., anthracite or petroleum coke.

The AISI, DIOS and HIs melt programs all plan to use non-coking coals. The Japanese steel companies involved in DIOS will test non-coking coals in the 20 – 35% volatile matter range. A target rate of 800 kg coal per tonne hot metal has been adopted. The HIs melt process has published a coal consumption rate of 640 kg coal (35% VM; 7400 kcal/kg) per tonne hot metal. The overall net heat requirements of the HIs melt are 3.64 versus 3.50 Gcal per tonne hot metal for the conventional coke/blast furnace. While the net energy demand is higher, the HIs melt process can "use lower cost coal".

* Coal U.S. \$50 per tonne; ore U.S. \$30 per tonne; electricity U.S. 4¢ per kWh; labour U.S. \$20,000 per year, maintenance 4% of equipment cost.

** U.S. \$2 per GJ.

7.5 TIMING OF NEW PROCESSES

The current activity to perfect the next generation of steelmaking process is due to the developing shortage of coke. This shortage will be compounded by industry's reluctance to build cokemaking capacity because of high capital cost and continuing environmental problems, even with new coke batteries.

Most coke capacity in the developed world is old and much of it has reached the end of its useful life. The situation in North America and Europe is worse than in Japan and South Korea. The closure rate of existing batteries will determine the timing for the new steelmaking technology. Measures that reduce the coke requirement in existing blast furnaces, such as wider adoption of PCI, will obviously affect the timing.

All industry/government people interviewed expressed the opinion that the last integrated greenfields steel plant using the coke/blast furnace route has likely been built, definitely so in North America, Western Europe and Japan. The consensus was that there would be additional Corex capacity built before 2000. A realistic estimate might be 2 – 3 mtpy by 2000. After that AISI, Hismelt and/or DIOS type processes should be commercially ready and capacity using these technologies will likely start to come on stream in significant quantities between 2000 – 2010.*

7.6 JAPANESE SITUATION

The Japanese Ministry of International Trade and Industry (MITI) has factored the new DIOS type smelting-reduction process into its long term planning. Mr. Yoshihico Adachi, Director of Iron and Steel Production Division, Basic Industries Bureau, MITI, in a 1990 interview⁽³⁾ stated that the 21st century Japanese steel industry would have two types of facilities. Blast furnaces suitable for large scale production would be used to make high volume products. The remaining demand, consisting of a large number of small volume speciality products, would be made with the new DIOS type process. Figure 7.1 was provided to demonstrate the production picture expected in the

"next generation". No date was provided for the timing of the next generation but it is probably not before 2005 – 2010.

While the Japanese coke ovens are newer than those in most other industrialized nations, the average age (1988 = 17 years) is still such that significant closures can be expected in the 1990s

The accepted average life of a coke battery is 25 – 30 years. If one assumes that a life of 35 years can be achieved with aggressive maintenance practices, the Japanese cokemaking capacity of 52 mtpy in 1986 declines as follows unless capacity is replaced as it closes:⁽³⁾

	Million tpy
1986	52
2000	44
2005	23
2010	14
2015	Nil

While wider acceptance of PCI and similar actions will stretch out the timing, by approximately 2005 it appears new steelmaking technology must be in place or new coke ovens must be built.⁽⁴⁾

Footnotes to Table 7.1

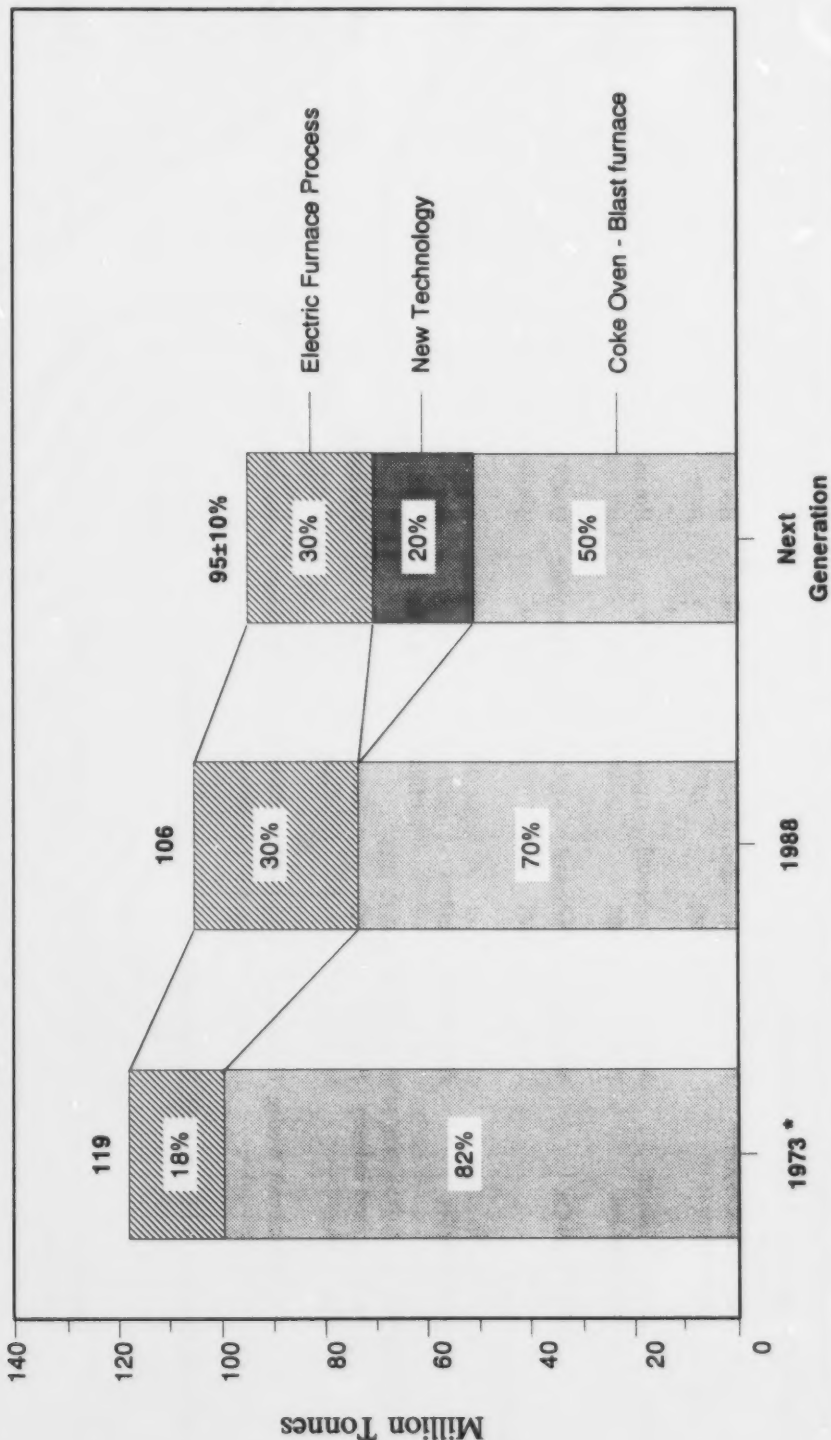
- (1) Reactants injected into a bath of molten iron.
- (2) Coal and FeO injected into reducer/gasifier unit contained molten iron.
- (3) From coal gasifier.
- (4) In a flash smelting chamber directly above the electric arc furnace, iron ore is reduced to FeO using reducing gases resulting from injection of coal and oxygen into the same chamber. Char forms in the chamber and falls with the FeO into the electric arc furnace.
- (5) Screw fed reactor tubes.
- (6) A conventional BOF converter.
- (7) Fine ore or metallurgical residues.
- (8) Coal, iron feed and fluxes are blown through a plasma torch. Lead and zinc impurities are volatilized as oxides and pass upwards through a shaft furnace packed with coke where they are reduced to metals and are recovered from the off gases.

* Note it took approximately 20 years between development of the basic oxygen furnace and its widespread adoption.

Figure 7.1

NEW TECHNOLOGIES

Share of Future Japanese Steelmaking Capacity



No. of Blast
Furnaces in Operation 60 Units
Continuous Casting Rate 20.7 %

37 Units
94.2 %

100 %

* Historical peak production year

Table 7.1

New Steel Processes Based on Coal not Coke

Process	Developer	Stage 1: Iron Ore Pretreatment				Stage 2: Iron Production Step			Combustion Gas		
		Iron Feed	Product	Reductant	Reactor	Product	Reductant	Reactor	Type	Point of Addition	
A. Direct Coal Reduction of Iron Ore to Hot Metal											
Hismelt	CRA Ltd./Klockner/Midrex	Fine ore	Preheated ore		Cyclone	Hot metal	Coal	Molten iron ⁽¹⁾	Air	Stage 2	
Foster Wheeler	Foster Wheeler/Tetronix	Fine ore	Preheated ore			Hot metal	Coal	Plasma furnace			
Plasmadust	SKF Steel Co.	Fine ore ⁽⁷⁾	Preheated - ore		Hot metal	Coal/Coke	Plasma	Air furnace ⁽⁸⁾	Stage 2		
B. Coal Reduction of FeO											
AISI	AISI/Doe ⁽⁹⁾	Ore pellets	FeO	Stage 2 offgas	Shaft furnace	Steel	Coal	Molten iron ⁽¹⁾	Oxygen	Stage 2	
DIOS ⁽¹¹⁾	Japanese steel industry	Fine ore	FeO	Stage 2 offgas	Fluid bed	Hot metal	Coal	Molten iron ⁽¹⁾	Oxygen	Stage 2	
KHD	KHD Humboldt Wedag	Fine ore	FeO (liq.)	Stage 2 offgas	Cyclone	Hot metal	Coal	⁽²⁾	Oxygen	Stage 2	
C. Prereduction of Iron Ore to DRI or FeO; Reduction to Metal in Electric Furnace											
(i) FeO											
Davy McKee	Davy McKee Research and Development	Fine ore	FeO	Stage 2 offgas	Fluid bed	Hot metal	Coke	Plasma furnace	Oxygen	Stage 1	
Elkem Polar	Elkem Technology	Fine ore	FeO	Coal gasifier offgas		Hot metal	Char ⁽³⁾	Electric arc furnace	Air	Coal gasifier	
INRED	Boliden	Fine ore or cinders	FeO (liq.)	Coal	⁽⁴⁾	Hot metal	Char ⁽⁴⁾	Electric arc furnace	Oxygen	⁽⁴⁾	

Table 7.1 - (Cont'd.)

New Steel Processes Based on Coal not Coke

Process	Developer	Stage 1: Iron Ore Pretreatment				Stage 2: Iron Production Step			Combustion Gas	
		Iron Feed	Product	Reductant	Reactor	Product	Reductant	Reactor	Type	Point of Addition
(ii) DRI ⁽¹⁰⁾										
Combismelt	Lurgi/Mannesmann-Demag	Lump; pellets	DRI	Coal	Rotary kiln	Hot metal		Electric arc furnace	Air	Stage 1
ELRED	Stora Kopparberg/ASEA/Lurgi	Fine ore	DRI	Coal	Fluid bed	Hot metal		Plasma furnace	Air	Stage 1
LB	McMaster University	Fine ore	Sponge iron	Coal	⁽⁵⁾	Hot metal		Plasma furnace	Air	Stage 1
D. Coal Gasified Separately; Offgas used to Reduce Iron Ore to DRI										
CBF	British Steel/Hoogovens	Ore	Sponge iron	Stage 2 offgas	Conventional blast furnace	Hot metal	Coal	Melter/gasifier	Oxygen	Stage 2
COIN	Krupp	Lump; pellets	DRI	Stage 2 offgas	Conventional blast furnace	Hot metal	Coal	Melter/gasifier	Oxygen	Stage 2
Corex ⁽¹¹⁾	Vöest-Alpine	Lump; pellets	DRI	Stage 2 offgas	Shaft furnace	Hot metal	Coal	Melter/gasifier ⁽¹²⁾	Oxygen	Stage 2
IMIS	Inst. Mexicana de Investigaciones Siderurgicas		DRI	Stage 2 offgas		Steel	Coal	Melter/gasifier ⁽⁶⁾	Oxygen	Stage 2
Plasmamelt	SKF Steel Co.	Ore	DRI	Stage 2 offgas	Fluid bed	Hot metal	Coal/coke	Plasma furnace ⁽⁸⁾	Air/oxygen	Stage 2

Primary Source: Strategic Study of Future Ironmaking Processes by Stelco Technical Services Ltd. Study funded by CANMET, CCRA, CSIRA and a number of Canadian companies Confidential Report, September 29, 1990.

- (9) American Iron and Steel Institute and U.S. Department of Energy.
- (10) Direct reduced iron containing 90 – 93% iron.
- (11) Five processes have been developed over the years by Japanese steel companies (CIG process by Japanese and Swedish organizations; Kobe process by Kobe Steel and Midrex; Nippon Steel process by Nippon Steel Co; Sumitomo SC process by Sumitomo Metal Industries; XR process by Kawasaki Steel Corp.) These have evolved into the joint venture DIOS project or been dropped.
- (12) Fluidized bed.
- (13) Originally called the KR (Kohn Reduction) process.

REFERENCES TO SECTION 7

- (1) Strategic Study of Future Ironmaking Processes, D.W.R. George, Stelco Technical Services Limited for Canada Department of Energy, Mines and Resources, September 28, 1990.
- (2) Interview B.A. Strathdee, D.H. Pomeroy, R.A. Kammermayer, Dofasco Inc., during this study.
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- (4) Tex Coal Manual, 1990.

8 COKE MANUFACTURE OPPORTUNITY

8.1 WORLD COKE CAPACITY IS AGING

Coke production has been declining in the industrialized world and increasing in developing nations. Table 8.1 demonstrates that the developing western nations have increased their share from 8% in 1970 to 20% in 1989. The only industrialized nation that has shown growth over the period is Japan. However, even Japan has lost total share since 1980.

The U.S. has shown the largest decline in coke production with its 1990 production only being 40% of the 1970 output.

Table 8.2 shows that cokemaking capacity in the industrialized nations is aging rapidly. The average age is seen to range from 17 – 23 years for

the industrialized and from 6 – 16 years for the developing nations. Figure 8.1 provides a ranking by country of average age of coke batteries at the end of 1988.

The generally accepted life of a coke battery is taken as approximately 25 – 30 years “but productivity may fall below the critical breakeven point well before this”.⁽¹⁾

IISI in 1989 forecasted closures and openings to 1995. This forecast is summarized in Table 8.3 and shows essentially no net change over the period 1988 to 1995 in overall world capacity. Closures are primarily in industrialized nations; additions, in developing countries.

Table 8.1

History of Coke Production by Major Regions

	Million Tonnes					Share - %	
	1970	1975	1980	1985	1989	1970	1989
DEVELOPED NATIONS							
Western Europe	100	89	80	70	63	44	34
U.S.	65	56	42	26	28	28	15
Japan	36	50	54	52	47	16	25
Canada	5	5	5	5	5	2	3
Australia	5	5	5	3	4	2	3
	211	205	186	156	147	92	80
DEVELOPING NATIONS							
Latin America	4	6	9	10	12	2	6
Africa	4	5	7	5	3	2	1
S.Korea	-	1	3	5	7		4
Taiwan			1	2	3 (1988)		2
India	9	9	12	12	11	4	6
Pakistan and Iran	—	—	1	1	1	—	1
	17	21	33	35	37	8	20
Total Western World	228	226	219	191	184	100	100
EASTERN BLOCK							
USSR					86		
China					59		
NK					3		
E. Europe					37		
					185		
TOTAL WORLD					369		

Source: IISI and U.S. Department of Energy.

Table 8.2
Age Profile of Western World Coke Capacity

Age in Years	Share of Effective Capacity - %				Average Weighted Age of Capacity (Dec. 1988)
	Under 16	Under 25	Under 30	Over 30	Years
Developed Nations					
West Europe	50	77	87	13	17
U.S.	45	60	65	35	23
Japan	20	98	100	Nil	18
Canada	36	76	80	20	21
Australia	30	89	96	4	17
Developing Nations					
Latin America	69	84	91	9	14
Africa	69	82	91	9	16
India	74	97	100	Nil	11
Pakistan		100	100	Nil	7
South Korea	94	100	100	Nil	7
Taiwan	41	100	100	Nil	6
Western Nations	47	83	89	11	17

Source: IISI

Figure 8.1
Average Age of Western World Cokemaking Capacity
as of Dec. 31, 1988

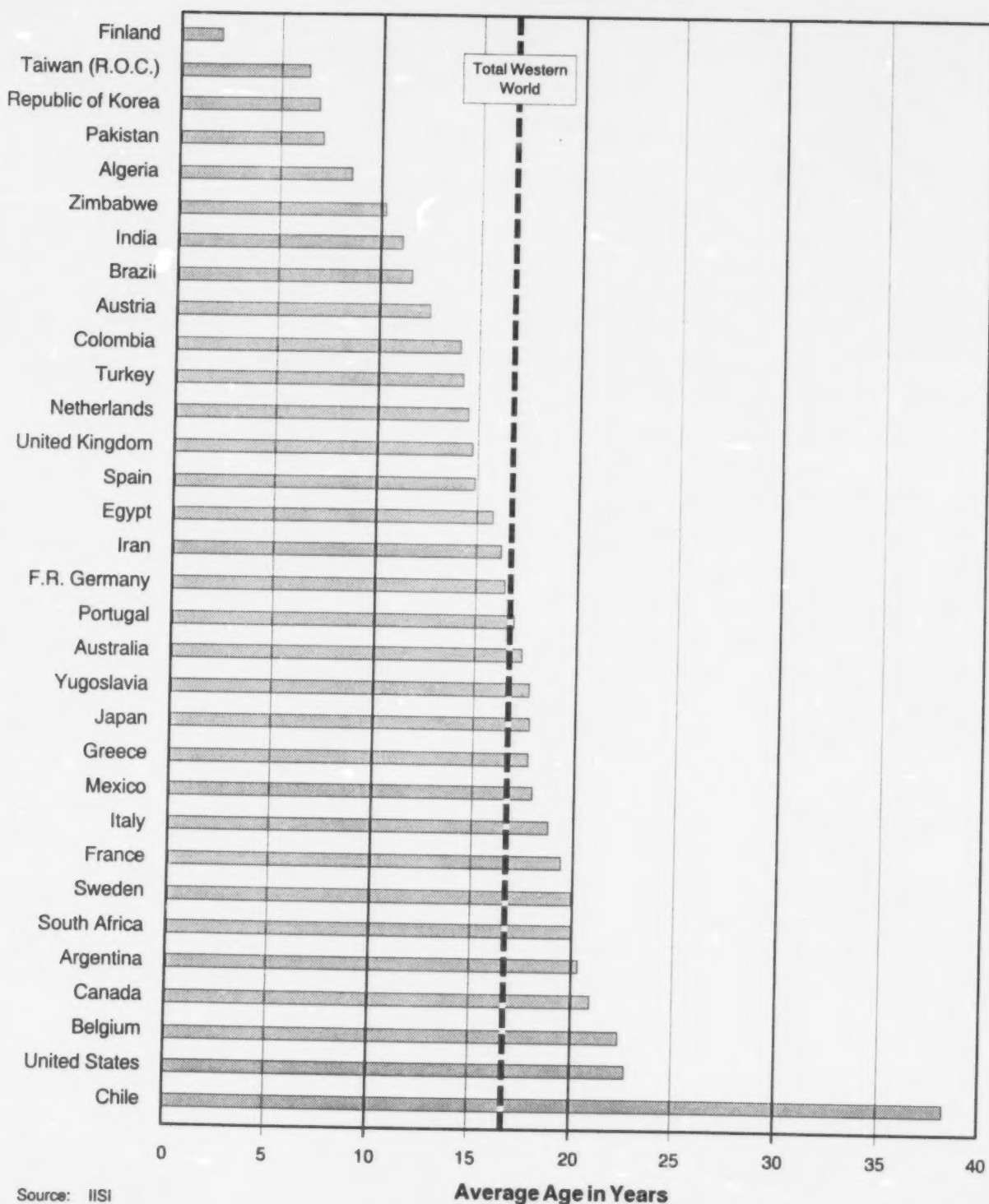


Table 8.3
IISI Forecast of Western World Coke Capacity by 1995
(million tpy dry coke)

	Effective Capacity December 31, 1988	Forecast Addition 1988-1995	Forecast Closures 1988-1995	Forecast Capacity 1995
A. DEVELOPED WORLD				
1. <u>Western Europe</u>				
W. Germany	21	3	4	20
Italy	9			9
France	8		1	7
U.K.	8			8
Belgium	6			6
Turkey/Yugoslavia	7			7
Other	10 ⁽¹⁾	1 ⁽⁵⁾	3 ⁽⁶⁾	8
	<u>69</u>	<u>4</u>	<u>8</u>	<u>65</u>
2. U.S.	30	4	5	29
3. Japan	50		5	45
4. Canada	5		1	4
5. Australia	5	1		6
Subtotal Developed	<u>159</u>	<u>9</u>	<u>19</u>	<u>149</u>
B. DEVELOPING WORLD				
1. Africa	9 ⁽²⁾			9
2. <u>Latin America</u>				
Brazil	8	3		11
Other	5 ⁽³⁾	1 ⁽⁷⁾	1	5
	<u>13</u>	<u>4</u>	<u>1</u>	<u>16</u>
3. <u>Asia</u>				
India	14	1		15
South Korea	8	1		9
Taiwan	3	1		4
Other	1 ⁽⁴⁾			1
	<u>26</u>	<u>3</u>	<u>-</u>	<u>28</u>
Subtotal Developing	<u>48</u>	<u>7</u>	<u>1</u>	<u>54</u>
Total West	207	16	20	203

Source: Western World Cokemaking Capacity, IISI, Brussels, 1989.

TABLE 8.3 FOOTNOTES

- (1) 30% Netherlands, 29% Spain, 17% Austria, 11% Sweden, 5% Greece, 4% Portugal, 4% Finland.
- (2) 57% South Africa, 14% Algeria, 14% Egypt, 10% Zimbabwe, 5% Morocco.
- (3) 45% Mexico, 28% Argentina, 14% Peru, 7% Colombia, 6% Chile.
- (4) 71% Pakistan, 29% Iran.
- (5) 40% Netherlands, 40% Spain, 20% U.K.
- (6) 50% Spain, 30% Netherlands, 8% Italy, 7% Austria, 5% Portugal.
- (7) 70% Chile, 30% Mexico.
- (8) 60% Mexico, 40% Chile.

8.2 WORLD TRADE IN COKE

The data in Table 8.4 indicates the scale of world trade in coke. While incomplete, the figure demonstrates that the trade is significant. In 1986 it totalled approximately 12 – 13 mt. While much of the trade was among neighbouring countries in western Europe and in eastern Europe, there was considerable offshore trade as indicated by the magnitude of Japanese exports and U.S. imports.

In the good steel market of the late 1970s, trade in coke accelerated and then dropped off during the slump in the 1980s. It picked up again with the good markets in 1988 and 1989 and is declining again as steel demand weakens.

It must be noted that the data in Table 8.4 does not distinguish between metallurgical grade used in steelmaking and foundry grade cokes. Foundry coke is quite different and made with different coal blends. The volume of foundry coke traded is smaller than that of metallurgical grade.

8.3 COKE SHORTAGE COULD OCCUR IN THE U.S.

In the periods 1975 – 1979 and 1988 – 1989, the U.S. imported large amounts of coke reaching peaks in 1978 of 5.2 mt and in 1988 of 2.4 mt. Imports in the 1975 – 1979 period were largely from Ruhrkohle in West Germany, but also some from Japan. Ruhrkohle had accumulated a large coke stockpile (peak of 22 mt). The Ruhrkohle stockpile no longer exists and in the 1988 – 1989 period the U.S. was less dependent on West Germany and more so on Japan. This dependence on Japan is shown in Table 8.5 which

details the sources of U.S. imports and destinations of Japanese exports. In 1978 the U.S. imported 69% of its coke from West Germany and 5% from Japan. In 1990, imports from West Germany had dropped to zero and Japanese imports increased to 44%.

It appears the U.S. is heading towards a serious shortfall in coke. RDI, Inc., Golden, Colorado,⁽²⁾ in a recent study agreed with this conclusion. It believes the Amended Clean Air Act will hit U.S. coke makers hard.

The USBM forecasts a severe shrinkage in capacity, 25% of 1991 capacity by 1995/1996 and a further 20% in 2003, will reduce U.S. cokemaking capacity to 13 – 16 mtpy. This shrinkage will result from:

- (1) Implementation of the Clean Air Act of 1990.
- (2) Aging capacity.
- (3) Minimal replacement.

As a result, the U.S. will have to meet the shortfall by importing coke. The quantity could be in the 6 – 8 mtpy range by 1991 – 1996.⁽³⁾

The National Coal Association⁽⁴⁾, CANMET and National Steel Corp. believe the U.S. steel industry will have to import coke when the next steel upturn occurs. This, they believe, might occur in the mid-1990s. The Ruhrkohle stockpile no longer exists and it is doubtful the U.S. can depend on Japan or Western Europe for significant supply. These countries will also face tight supply situations. Several experts interviewed expressed the opinion that coke manufacture in B.C. to supply the U.S. market at least warrants examination.

IISI concurs that more U.S. closures can be expected: "moreover with an overall (weighted) average oven age of over 22 years, further large scale closures of cokeries in the United States are clearly foreseen".⁽¹⁾

Should a coke shortfall occur, it would likely be most severe in the Chicago area, followed by Ohio and last by Pennsylvania. National Steel, Inland Steel, LTV Corp. are reportedly short of coke. Weirton Steel Co., McLouth Steel Products Corp. and Rouge Steel have no coke capacity and buy their requirements. These three companies are reportedly in financial difficulty and would likely

Table 8.4
World Trade in Coke ⁽¹⁾⁽²⁾
(Million Tonnes)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
A. EXPORTS																
Western Europe																
West Germany	7.6	6.8	6.2	8.1	11.0	7.8	6.0	3.9	3.1	6.6	5.1	3.5				
Other	2.9	1.9	1.6	3.5	4.3	4.3	5.0	5.1	3.2	3.2	4.4	4.0	2.3			
Japan	10.5	8.7	7.8	11.6	15.3	12.1	11.0	9.0	6.3	10.5	9.5	7.5				
(JFY to 1986)	0.5	0.6	0.5	1.0	2.2	2.1	2.0	1.6	2.2	2.3	2.3	2.5	3.4	2.9	2.6	
Canada		0.2			0.2					0.1						
Eastern Europe																
Poland	3.0		2.7	2.1	2.0	1.8	1.4	1.7	1.6	1.8	1.6	1.5	2.3			
Czechoslovakia	2.1	2.1	2.0	1.8	1.9	1.5	1.4	1.7	1.6	1.8	1.6	1.5	1.5			
	5.1	2.1	4.7	3.9	3.9	3.3							3.8			
B. IMPORTS																
Western Europe	11.2	5.2	8.9	8.9	13.0	11.7	10.9	8.4	8.9	11.4	10.6	8.8 ⁽⁴⁾				
U.S.	1.7	1.2	1.7	5.2	3.6	0.6	0.5	0.1	0.03 ⁽¹⁾	0.5 ⁽¹⁾	0.5 ⁽¹⁾	0.3 ⁽¹⁾	0.8 ⁽¹⁾	2.4 ⁽³⁾	2.1 ⁽³⁾	0.7 ⁽³⁾
Canada		0.3	0.4	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.7	0.5	0.3			
Taiwan, Singapore, Thailand, Philippines																
Romania, Hungary, E. Germany, Bulgaria	7.3	4.0	4.5	4.1	1.6	5.1	1.6	3.2	3.2	3.3	3.6	3.6				

(1) Primary Source: Tex Coal Manual.

(2) Data incomplete; not all trade shown as not available.

(3) Source: U.S. Energy Information Agency

(4) 27% Benelux, 16% France, 13% Finland, 10% Austria, 34% other.

Table 8.5

Source of U.S. Coke Imports and Destination of Japanese Exports

	1978	1980	1988	1989	1990
A. U.S. IMPORTS⁽¹⁾					
Quantity mt	5.2	2.4	2.1	0.7	
<u>Source - %</u>					
Japan	5.0			30.0	44.0
Australia				21.5	29.0
West Germany	69.4			19.6	
Other W. Europe				11.8 ⁽⁷⁾	5.2
Canada/Mexico				9.2	21.8 ⁽⁸⁾
Poland				4.8	
China				3.1	
Other	<u>25.6</u>				
	<u>100.0</u>			<u>100.0</u>	<u>100.0</u>
B. JAPANESE EXPORTS⁽²⁾					
Quantity mt	1.0	2.1	2.9	2.6	
<u>Destinations - %</u>					
U.S.		8.5	39.7		
<u>Asia</u>					
Philippines		8.8	9.2		
Taiwan		4.6	5.7		
S. Korea		4.7	4.3		
Other		<u>11.6</u>	<u>6.9⁽³⁾</u>		
		29.7	26.1		
Latin America		32.1	18.7 ⁽⁴⁾		
W. Europe		6.5	3.5 ⁽⁵⁾		
Romania and Bulgaria		<u>23.2</u>	<u>12.0⁽⁶⁾</u>		
		100.0	100.0		

(1) U.S. Energy Information Agency.

(2) Tex Coal Manual.

(3) 22% Thailand, 22% India, 17% North Korea, 13% Indonesia, 11% Malaysia, 8% Singapore, 6% Australia, 1% Bangladesh and Hong Kong.

(4) 79% Brazil, 17% Chile, 4% Venezuela.

(5) 53% Spain, 36% U.K., 11% West Germany.

(6) 94% Romania.

(7) 38% Belgium, 22% U.K., 19% Yugoslavia, 14% France, 7% Netherlands.

(8) 80% Canada.

buy in the long term rather than build cokemaking facilities. Sharon Steel, previously a major buyer of coke, purchased a coke plant. Armco Steel is one of the few steelmakers long on coke supply.

Inland Steel (Chicago), Bethlehem Steel (Burns Harbour), Weirton Steel and LTV (Cleveland), are all evaluating new coke batteries. Rather than build itself, Weirton is considering purchase of coke from a company proposing to pay for and construct a coke battery for Weirton's needs. National Steel is considering rebuilding of an old battery, probably its last. ⁽¹⁾

While coke facilities in Japan are more modern than those in the U.S., the average age is such that closure of some capacity in the 1990s seem likely. It appears the Japanese steel industry has no intention of replacing it.

8.4 JEWELL-THOMPSON COKE OVENS

Inland, Weirton and LTV are all considering the Jewell-Thompson, non-recovery beehive process. Armco is also evaluating this technology.

The Jewell Coal and Coke Company, a subsidiary of Sun Coal Company,* developed and operates the only non-recovery beehive coke battery in the U.S. Located in southwestern Virginia, the plant produces about 0.6 mtpy coke for the merchant market. The process was developed by B.R. Thompson and involves operation of simple beehive coke ovens under slight vacuum. The volatile components of the coal are simply combusted within the oven. They are not collected and processed for the recovery of coal chemicals and tars as in the conventional cokemaking process.

Because of the beehive design, lateral expansion pressure, a severe constraint in conventional ovens, is of no importance. Consequently, coke can be made from any blend of coking coals, irrespective of the swelling characteristics of the coal. 100% low volatile coals are suitable feeds. The process produces high quality coke and emissions are "well within regulatory limits".

Because the total volatile content of the coal feed is burned, the quantity of waste heat produced is

large and must be recovered for power generation or some other industrial use.

Providing an outlet for the waste heat exists in B.C., it was recommended that serious consideration be given to this technology should coke manufacture appear warranted.

8.5 ECONOMICS OF COKEMAKING

8.5.1 Capital Cost

Only very approximate estimates were obtained in the study. Manufacturers were not contacted. Nippon Steel in April, 1990, stated the cost to rebuild a coke battery is approximately U.S. \$100 m.⁽⁷⁾ National Steel stated an 0.8 mtpy rebuild in the U.S. would cost about U.S. \$100 m assuming the basic oven pads and the recovery plant were usable. For a total new plant a cost of U.S. \$400 m was suggested.⁽⁵⁾ Hatch, in June, 1989, stated a coke battery rebuild would cost U.S. \$80 million and, at the then spread between the cost of internal coke and purchased coke of U.S. \$33 per tonne, would yield a payback of 6.5 – 8.5 years (for a plant to service 880,000 tpy hot metal).⁽⁶⁾

Essentially the only engineering firms left in the design and construction of coke batteries are in Germany and Japan. Kruppe Koppers GmbH, Essen, Germany, bought out the last North American company, Wilputte Corp. Kruppe Wilputte Corp. has offices in Murray Hill, New Jersey and Chicago.

As a rough approximation, a Jewell-Thompson non-recovery plant would cost in the order of U.S. \$100 – \$150 m. If an attendant power plant were built to utilize the waste heat, the cost would increase to U.S. \$350 – \$400 million.

8.5.2 Operating Cost

The conversion cost of converting coal to coke in a conventional operation is reported to be in the range of U.S. \$45 per t dry coke, exclusive of coal cost and by-product credits, but including maintenance. Coal cost in the U.S. is typically U.S. \$57** per t coke and by-product credits U.S. \$20 per t coke. Using these figures, the cost of coke is, consequently, (45+57-20) U.S. \$82 per

* Sun Coal owns six coal companies in the U.S. producing approximately 23 mtpy steam and coking coals. It is a subsidiary of Sun Oil.

** 1.3 t coal/t coke; cif coke plant price of U.S. \$44 per t coal feed.

tonne. The range was stated to be U.S. \$75 – \$120 per t. The USBM said the reported conversion cost is about U.S. \$28 per t, but the range is wide as some companies include overhead and administration costs; others, do not.⁽³⁾

The conversion cost of coal to coke in the Jewell-Thompson non-recovery oven would be less than in a conventional plant because both maintenance and manpower requirement (1/4 to 1/3 of conventional) are appreciably less. A cost of U.S. \$35 per t coke was suggested as a first pass assumption.⁽⁸⁾

8.5.3 Coke Price

The current cost of captive coke in the U.S. is approximately U.S. \$85 per t, fobt coke battery. Purchased coke currently sells for about U.S. \$115 – \$120 per t delivered to steel mill*. This price is depressed and a more normal delivered price is closer to U.S. \$150 – \$155 per t. One contact hazarded a guess that should a serious coke shortage develop, the delivered price might reach U.S. \$200 per t (the price in the last shortage, in 1989, reached U.S. \$170 per t.) The USBM thought the industry might see delivered prices in the next period of shortage in the U.S. \$180 per t range.⁽³⁾

8.5.4 Rough Estimate of Return on Investment of Coke Production in B.C.

If the major assumptions are made that:

- (a) A 0.8 mtpy non-recovery Jewell-Thompson design is constructed;
- (b) The waste heat can be fed into an existing power plant at no cost to the coke plant;
- (c) Coke can be sold in the Chicago area for a delivered price of U.S. \$180 per t; and
- (d) The plant is in southeast B.C.

The economics of a B.C. plant might approximate: (Table 8.6)

Table 8.6	
	U.S. \$ per t Coke
Operating Cost	
Conversion cost	35
Coal (1.5 t at 30 per t)	45
	80
Freight	30
Depreciation	
\$150 m over 10 years	20
Interest 10% per year	
on 1/2 the capital	10
Cost before taxes	140
Revenue	180
Profit before Taxes	40
Simple ROI before taxes	25 %

While extremely rough, these numbers indicate the concept of a coke plant in B.C. might merit investigation. The calculation ignores potential revenue to the coke plant from sale of by-product heat (to a power plant (?)).

In 1987 the First International Cokemaking Congress was held in Essen, West Germany. A conclusion from that meeting was coke consumption will continue to decline. However, even if coke demand fell to 1/2 its present level," it would still pay to invest in construction of new coke plants." Good markets will still exist because the "great part of the existing coking plants is obsolete and that stricter pollution control requirements can be met very often only by revamping existing plants or by constructing new ones".⁽⁹⁾

* Average freight cost from merchant coke plant or import port is about U.S. \$17 per t.

REFERENCES TO SECTION 8

- (1) Western World Cokemaking Capacity. IISI, Committee on Raw Materials, Brussels, 1989.
- (2) Coal, January, 1991.
- (3) Interview T. Peters, USBM during this study.
- (4) Interview C. Holmes, National Coal Association during this study.
- (5) Interview J.A. Raines and K.R. Hass, National Steel Corp. during this study.
- (6) Plasma as a Blast Furnace Supplement. Hatch Associates Consultants Inc., for Center for Metals Production, June, 1989.
- (7) Market Force Impact on Demand. K. Tanaka, Nippon Steel Corp., Australia Japan Coal Conference, April 29, 1990.
- (8) Interview J.J. Knoerzer, Sun Coal Co., during this study.
- (9) State of the Art of Development Trends of Cokemaking Technology. Conclusions from the First International Cokemaking Congress held in Essen, September, 1987. D. Springorium, IISI, Technical Exchange Session, Brussels, April, 1988.

APPENDIX B.

Appendix B. THE IMPACT OF CLEAN COAL TECHNOLOGY ON THE USE OF THERMAL COAL FOR ELECTRIC POWER GENERATION.

Chapter 12.2 discussed a number of technologies that are evolving in the electric power generating industry. All of the technologies described are related to the continued use of coal and are designed to increase efficiency with significant reductions in the amount of gaseous, liquid and solid emissions to the environment.

These technologies are being developed in North America, Europe and Japan. Ultimately, the entire world will benefit from the results of this work.

The following describes these technologies in greater detail than that presented in the main body of the report. A description of these technologies, by nature, tends to be fairly complex. In this regard Mr. M. M. McDonald, Manager of Research, TransAlta Utilities Corporation, one of Canada's largest coal burning electric utilities, has prepared an excellent summary of each technology. Much of the following are direct excerpts from these summaries with the kind permission of TransAlta Utilities Corporation.

"Clean coal" power generation technologies which will be coming available over the next 25 years can be grouped as follows:

Developments in conventional power generation:

- pulverized coal firing; and
- atmospheric fluid bed combustion.

Advanced coal utilization technology:

- pressurized fluid bed combustion;
- integrated gasification combined cycle;
- integrated gasification fuel cells;
- advanced hybrid cycles;
- magnetohydrodynamics; and
- direct coal fired gas turbines.

There are a number of conditions which have to be met before a technology can be applied successfully. First, a technology must provide the

degree of environmental protection required by legislation and by the community in which it is to be applied. Secondly, it must be cost effective for the utility to apply the technology. This is perhaps the biggest hurdle for many of the new technologies discussed below. Many of them promise a great improvement in efficiency and environmental cleanliness but at the present stage of development appear to be considerably more expensive than conventional coal burning technology. While others, under site specific conditions, are now either economically viable or are approaching economic viability.

Developments in Conventional Power Generation

Coal (and oil and gas) fired power generation make use of the conventional steam electric plant design using the Rankine Cycle. This requires a boiler to generate steam at high temperature and pressure which is then expanded through a multistage turbine. The steam leaving the turbine is generally at sub-atmospheric pressure and is condensed in a condenser requiring a large flow of cooling water in which to reject the heat.

The overall cycle efficiency is limited by the steam conditions leaving the boiler, and these in turn limited by the metallurgy of the materials used. Generally, pulverized coal is the preferred firing system, although fluid bed combustion has been developed over the last decade to reduce the emissions of the acid gases.

Since about the early 1970s, a range of technologies have been developed which reduce the emissions produced by conventional coal fired boilers. These can, for convenience, be grouped as in-furnace controls and flue gas controls shown in Table 1. In general, these technologies address either NO_x or SO_2 emissions, although some are effective on both NO_x or SO_2 . Table 1 provides the approximate performance potential for the technologies and the development status. Many of

these technologies can be applied to any combustion process which requires flue gas cleanup; however, for convenience they are included here.

These technologies can make a significant difference. It is anticipated in Germany that, by the early 1990s, emissions of sulphur dioxide will be reduced by about 80 per cent and NO_x by about 75 per cent when compared to the emissions of the early 1980s. (Diehl, 1989) This will have been achieved mainly using flue gas scrubbers and selective catalytic reduction technologies.

The technologies listed in Table 1 will be briefly described.

Developments in Pulverized Coal Firing

Low NO_x Combustors

These combustors control the mixing of air and fuel by staging the air or fuel in such a way so to promote the conditions most likely to reduce the nitrogen contained in the fuel to molecular nitrogen. Designs are available for retrofitting in existing boilers, and this can be combined with sorbent injection to control both acid gas emissions. One limiting factor with the use of these burners is the tendency to reduce the burnout of the fuel, resulting in an increase of unburned carbon.

Re-burning

Re-burning refers to a furnace combustion

modification in which additional burners are installed above the overfire air ports. The main burners operate at a reduced firing rate, approximately 80 per cent, and at slightly lean conditions. In the upper zone of the furnace, the balance of the fuel is injected at fuel rich conditions. Final dilution air is then added. By controlling the temperature and residence time, the NO_x formed at lower burners can be reduced in the presence of OH and H_2 species in the upper burner flames.

Sorbent Injection

Sorbent injection refers to the injection of a sorbent, generally calcium based, into the furnace above the flame. At the appropriate temperature conditions, and with proper mixing, a significant percentage of the sulphur dioxide will react with the sorbent and be captured as a solid residue. Sorbents include limestone (calcium carbonate), lime (calcium oxide) and slaked lime (calcium hydroxide), as well as dolomite (calcium and magnesium carbonates).

Advanced Slagging Combustors

Advanced slagging combustors refer to a groups of combustors developed over the last 10 years in which the temperature is raised to a sufficiently high level to allow the ash to melt. These burners also control the mixing of the air and fuel in such a way that the production of NO_x

Table 1 Conventional Power Generation Technology			
Technology	Pollutant	Control Level	Status
In-Furnace Controls			
Low NO_x combustors	NO_x	40% – 60%	Commercial
Re-burning	NO_x^1	~ 40%	Demonstration
Sorbent Injection	SO_2	30% – 50%	Demonstration
Advanced Slagging combustors	NO_x & SO_2	Up to 90%	Demonstration
Flue Gas Controls			
Duct injection and Humidification	SO_2	70% – 80%	Demonstration
Selective Catalytic Reduction (SCR)	NO_x	75% – 85%	Commercial ²
Non-Selective Catalytic Reduction	NO_x	60% – 70%	Demonstration
Scrubbers for Sulphur dioxide	SO_2	80% – 90%	Commercial
Combined flue gas cleanup	NO_x & SO_2		Development
Atmospheric Fluid Bed Combustion	NO_x & SO_2	75% – 90%	Commercial
Notes: 1. When natural gas is used as a reburning fuel, reduction in CO_2 and SO_2 emissions result. 2. SRC is used commercially in Germany and Japan on coal fired boilers, but not in N. America.			

is suppressed. Sulphur dioxide is also controlled in some of the designs, either by injection of a sorbent which neutralizes it, or by control of the temperature - time history of the gases and by binding the sulphur in the fused ash. These burners can be used in retrofit applications and in modified new boiler designs.

Duct injection and Humidification

Duct injection refers to the addition of sorbents to the flue gas ducting before or after the air heater. For this low temperature application, sodium bicarbonate is most effective, although some calcium based sorbents have been reported to perform well. In other cases, the calcium based sorbents can be injected into the furnace and by humidification of the unreacted dust in the ducting, significantly greater captures of sulphur dioxide can be obtained.

Selective Catalytic Reduction (SCR)

In the SCR processes, a reducing compound such as ammonia is injected into the flue gas ducting upstream of a catalyst at temperatures of 350°C to 450°C. The catalyst selectively assists the ammonia to reduce the NO_x to nitrogen without converting the ammonia to NO_x or the SO_2 to SO_3 . The SCR process has been widely used in Germany and Japan, but not generally on high sulphur coal applications. Italy plans to introduce this technology in a large scale over the next 10 years. Approximately 68 plants totalling 32 GW will be installed by 2000 (Basso, 1990).

Non-Selective Catalytic Reduction (NSCR)

This process is similar to SCR, but no catalyst is used. As a result, the process operates at a much higher temperature, around 950°C. This requires that the system is integrated into the boiler heat recovery section, and makes retrofit applications difficult. The chemical reactions operate effectively in a fairly narrow temperature window so the performance may vary with boiler operating conditions. The advantage is that the fairly expensive catalysts are not required.

Scrubbers for Sulphur Dioxide

Scrubbers have been in use in the United States, Germany and Japan for some years. Many different processes have been developed but those based on limestone are the most common. Most processes produce a large volume of sludge

composed of calcium sulphite which is difficult to dewater and requires large ponds for disposal. Newer processes oxidize the sulphite to sulphate, or gypsum, which can be used for the manufacture of wallboard and reduce or eliminate the disposal problem. In England, the largest coal fired plant in Europe, the 4000 MW Drax plant, is being retrofitted with wet limestone scrubbers. This will reduce the sulphur emissions from the 35,000 tonnes per day of coal burned by 90 per cent and produce 800,000 tonnes of gypsum a year for use in the production of wallboard. (Conway, 1991)

Combined Flue Gas Cleanup

A number of processes are under development which promise high removal efficiencies of both NO_x and SO_2 . In some cases the sulphur is recovered as sulphuric acid, a commercially important chemical, or as a fertilizer.

The processes include new post-combustion control systems giving more than 90 per cent removal of both NO_x and SO_2 ; in boiler processes making use of two complimentary processes to reduce the NO_x and SO_2 , such as sorbent injection and low NO_x burners; and modifications to existing flue gas desulphurization processes to enable the NO_x to be captured at high efficiency. (Makansi, 1990) These processes have yet to be adopted commercially on a large scale.

Atmospheric Fluid Bed Combustion (AFBC)

Fluidized bed combustion development has made rapid progress over the last 15 years. From being a laboratory curiosity it is now the accepted technology for the combustion of a range of low quality and high sulphur fuels. It is now being applied widely across the world. In excess of 2500 fluid bed boilers are currently estimated to be in operation around the world and power plants can be supplied at up to 300 MW.

In a fluidized bed combustor, the crushed fuel and ash is subjected to the force of the combustion air being injected at the bottom of the bed. This lifts the material, and supports it so that it behaves similarly to a fluid. Turbulent mixing takes place and bubbles of gas can be seen rising through the bed. Fluid beds can be described as bubbling, in which the bed material remains in the bed at all times; or circulating, in which the higher air velocities cause the bed material to be circu-

lated out of the bed where it is separated from the flue gas by cyclones or other particulate separation device, and returned to the bed. In both types of bed the ash produced is drained from the bed to maintain a set amount of material in the bed.

The advantage of fluid bed combustors is that, by operating at moderate temperatures of around 850°C, a large proportion of the sulphur in the fuel can be captured by limestone added to the bed. Between 80 per cent and 90 per cent can be captured in this way. The low temperature also limits the amount of NO_x formed, and the careful control of the combustion air can reduce this to levels below 100 ppm; for many coals in convention boilers this represents an 80 per cent reduction in NO_x emissions. The turbulent bed also makes combustion of difficult, high moisture or ash fuel possible with a high level of carbon burnout.

In Canada, a two unit bubbling bed plant was installed at C.F.B. Summerside, PEI, in 1982, and New Brunswick Power installed a demonstration unit using circulating bed technology at Chatham in 1986. Nova Scotia Power is now constructing a 165 MW plant at Point Aconi, N.S. for start up in early 1993, which will be the largest circulating fluid bed power plant in operation.

Advanced Coal Utilization Technology

There are a number of advanced coal technologies under development which not only promise major reductions in the emissions of the acid gases, but also make use of cycles which are

not limited to the Rankine cycle efficiencies of 37 to 38 per cent. These technologies employ gas turbines, fuel cells and direct power generation from high velocity electrically conducting gas streams to achieve higher efficiencies which could bring efficiencies to 50 to 60 per cent in the next twenty-five years. This allows significant reductions in carbon dioxide emissions per unit electrical output to be achieved.

Table 2 summarizes the potential performance of these in terms of emissions and cycle efficiencies. Likely dates of commercialization are also included. Each of these technologies is described below.

Pressurized Fluid Bed Combustion (PFBC)

In pressurized fluid bed combustion, the pressurized gases from the bed can be expanded through a turbine to provide an integrated cycle giving greater efficiency. It also improves the rate of the combustion reaction and allows the heat release rate per unit cross section of the bed to be increased significantly, thus reducing the size of boiler required for a given duty. A flow diagram of a first generation plant is shown in Figure 1.

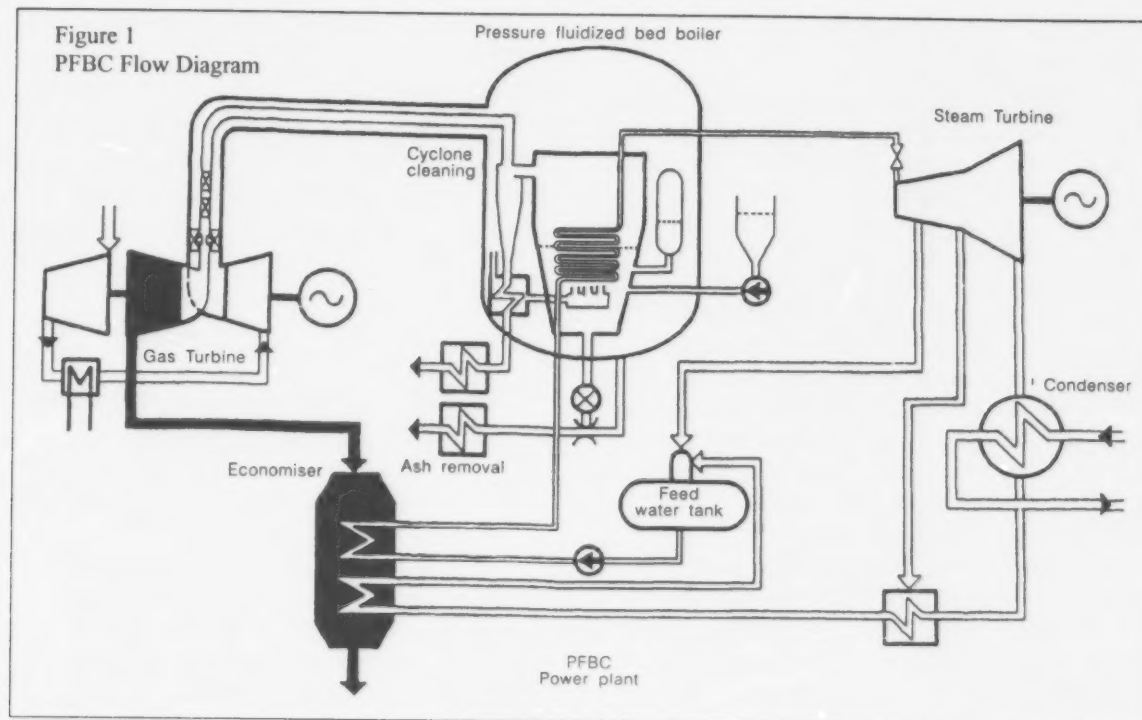
Air is first compressed in the compressor section of the gas turbine and is piped to the FBC boiler. The coal and limestone are added to the bed which is enclosed by a pressure vessel, and the released heat is removed by buried coils in the bed, generating steam. The hot gas, which has reduced levels of sulphur dioxide, passes through cyclones

Table 2

Technology ¹	Emission Reduction % ²		Cycle Efficiency %	Commercialization Date
	NO _x	SO ₂		
PFBC	~ 75	~ 90	40 - 42	1995
IGCC	~ 80	To 99	41 - 45	1997
IGFC	99+	99+	45 - 58	2010
Advanced Hybrid Cycles ³	~ 80	To 99	40 - 45	2000
MHD	~ 80	~ 95	50 - 60	2015
Direct Coal Fired GT	80+	80+	43 - 48	2010

Note: 1. PFBC: Pressurized Fluid Bed Combustion
 IGCC: Integrated Gasification Combined Cycle
 IGFC: Integrated Gasification Fuel Cell
 GT: Gas Turbine.
 2. Approximate reduction based on conventional coal fired power plant, no add flue gas cleanup.
 3. Cycles based on partial gasification of the coal combustion of residue in atmospheric or pressurized fluid bed boilers.

Figure 1
PFBC Flow Diagram



to remove the particulate material, and is expanded in the turbine section of the gas turbine, generating electricity. The flue gas then flows through an economizer and the steam from the boiler is used in the steam turbine. This is equipped with a condenser as in a conventional cycle.

This development is not without problems however. To be successful, the expansion turbine must be able to survive the impacts of residual particulate material from the bed. Most of the development effort is focused on this issue, with the problem being attacked from two directions: by developing an effective particulate removal system, and by developing a "ruggedized" turbine which can withstand greater amounts of particulate impingement than can a conventional unit.

Several demonstration plants are in operation or about to start up. (Pillai, 1989) Stockholm Energi, the main producer of district heat in Stockholm, has installed a PFBC unit to produce about 135 MW of electricity and 220 MW of heat to the heating system. Overall efficiency will be of the order of 89 per cent. Expected emissions of 30 ng/J for SO_2 , and 60 ng/J for NO_x result in reductions in the 80 to 90 per cent range. Two fluidized

bed boilers are integrated with two gas turbines, each producing about 17 MW.

American Electric Power has started up a demonstration project at the Tidd plant at Brilliant, Ohio during the fall of 1990. This plant, a conversion of a mothballed plant, will produce around 70 MW using a 4 per cent sulphur coal. A third plant is being built by the Spanish utility ENDESA. This is planned to burn lignite containing 4 to 8 per cent sulphur, 25 to 45 per cent ash, and up to 20 per cent moisture. An existing 62 MW plant at Escatron is being repowered to produce 80 MW. Limestone added to the bed will capture 90 per cent of the sulphur.

While PFBC offers some attractive features, the efficiency of the basic cycle is limited by the gas turbine inlet temperature, which in turn is limited to around 850°C to 950°C for optimum sulphur capture. As the gas turbine efficiency is largely a function of temperature, this constraint limits cycle efficiency. To remove this constraint, several hybrid cycles have been proposed, which include a pyrolysis or partial gasification stage to generate a gaseous fuel with which the gas turbine can be fired prior to expansion. These cycles are discussed under Advanced Hybrid Cycles.

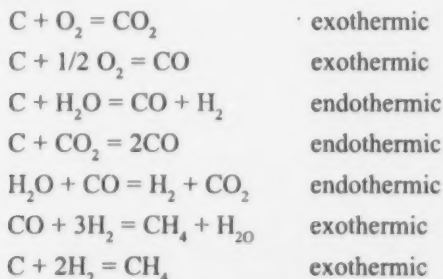
Coal Gasification Processes

Fundamentals

The fundamental process in the gasification of coal is partial oxidation with oxygen (or air) and steam under reducing conditions. This results in the majority of sulphur compounds being converted to hydrogen sulphide, and the fuel nitrogen to nitrogen and ammonia. The actual composition of the synthesis gas, mainly hydrogen, carbon monoxide and some carbon dioxide, is dependent on the relative feed rates of oxygen, steam and coal and the temperature and pressure at which the conversion process takes place. Heating values of the synthesis gas are dependent mainly on whether the process is fed by air or oxygen, resulting in low heating value gas (3.75 to 6.5 MJ/m³) for air blown processes and medium heating value gases (10 to 12 MJ/m³) for oxygen blown processes. This can be compared to natural gas which has a heating value of around 37.25 MJ/m³.

Only a fraction of the carbon in the coal is oxidized completely to carbon dioxide, and this provides the major portion of the energy required to maintain the gasification reactions. The coal introduced to the gasifier is first dried by evaporation of the surface and inherent moisture. This is followed by devolatilization as the temperature rises. Tars, phenols and hydrocarbon gases are formed, whose fate depends on the gasifier conditions.

The remaining fixed carbon is gasified by reactions with oxygen, steam, carbon dioxide and hydrogen, with the following reactions being important:



The operating temperature and pressure is important in determining equilibrium concentrations of the gases produced. Methane formation is favoured by high pressures and low temperatures and is generally not the most prominent reaction in most processes. Methane formation is important as it is highly exothermic and thus higher yields

reduce oxygen and steam requirements and thereby improve efficiency.

Gasification Process

A large number, approximately 50, of gasification processes have been developed and can be grouped into three main types of reactors:

- Fixed bed, in which coal in a bed of fixed depth slowly moves down through the reactor, with the gas moving in counterflow. This is sometimes known as a moving bed reactor.
- Fluid bed, in which the introduced gases agitate or fluidize the coal particles.
- Entrained flow, in which the feed coal is entrained in the flow of oxidant and steam and rapidly gasified.

The three main types of gasification processes are described below. Table 3 gives the important characteristics of the three gasifier types and illustrates the differences between them. A number of processes have now been developed to the point of demonstration or commercialization. These processes include the British Gas Lurgi (BGL) fixed bed, KRW and HT Winkler fluid bed, and the Dow, Shell and Texaco entrained flow processes. Major characteristics of these processes are summarized in Table 4.

Fixed Bed

The fixed bed is typified by the Lurgi gasifier shown in Figure 2. In this type of reactor, the coal is introduced at the top of the vessel via a lock hopper and slowly moves down through the gasifier before being removed as ash at the bottom. At the same time, gases flow upward through the coal, which undergoes a series of changes from inlet to exit. This can be described in a series of reaction zones.

As the coal enters at the top, it is first heated and moisture is driven off in the drying zone. This is accompanied by a cooling of the product gas before it leaves from the top of the vessel. The coal is further heated and devolatilized by the hotter product gas and moves down through the carbonization zone. Below this level, it is gasified by reaction with steam and carbon dioxide in the gasification zone. At the bottom of the gasifier, the remaining carbon is completely burned by the oxygen reacting with the remaining char.

Table 3
Important Characteristics of Generic Types of Gasification Reactors

Ash Conditions	FIXED BED		FLUID BED		ENTRAINED FLOW	
	Dry Ash	Slagging	Dry Ash	Agglomerating	Slagging	
Feed Coal Characteristics						
Size	Coarse (-50 mm)	Coarse (-50 mm)	Crushed (-6.3 mm)	Crushed (-6.3 mm)	Pulverized (-100 mesh)	
Acceptability of fines	Limited	Better than dry ash	Good	Better	Unlimited	
Acceptability of Caking Coal	Yes (with modifications)	Yes (with modifications)	Possibly	Yes	Yes	
Preferred Coal Rank	Low	High	Low	Any	Any	
Operating Characteristics						
Exit Gas Temperature	Low (425°C - 650°C)	Low (425°C - 650°C)	Moderate (925°C - 1040°C)	Moderate (925°C - 1040°C)	High (1260°C)	
Oxidant Requirement	Low	Low	Moderate	Moderate	High	
Steam Requirement	High	Low	Moderate	Moderate	Low	
Key Distinguishing Characteristics	Hydrocarbon liquids in the raw gas		Large char recycle		Large amount of sensible heat energy in the hot raw gas	
Key Technical Issue	Utilization of fines & hydrocarbon liquids.		Carbon conversion		Raw gas cooling	

Source: Simbeck (1983)

Table 4
Gasification Process Summary

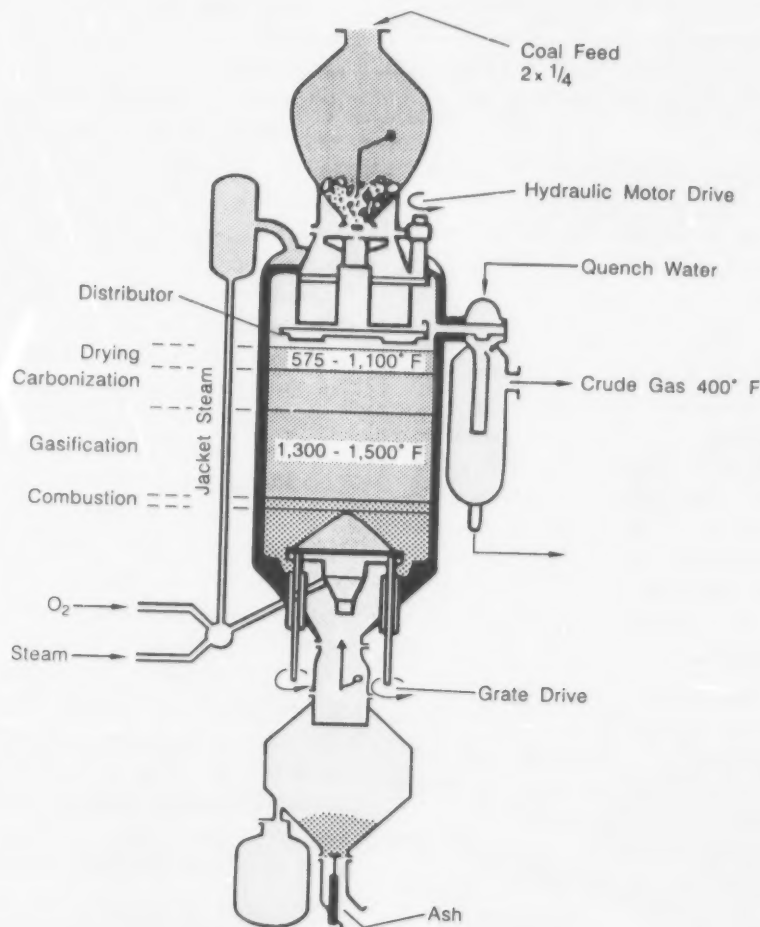
Items	Units	Process
Process Type		
Status		HT Winkler Fluid Bed
Operating Conditions		Entrained Flow Demonstration
Temperature	°C	Up to 1950
Pressure	MPa	2.8
Coal Feedstock		4.1
Rank		All ranks
Size	mm	90% less than 100 Mesh
Feed Method		Lock Hopper
Oxidant		66% Slurry with Water
Typical Gas Produced	Mole %	Oxygen
Dry Basis		CO 49.6%, H ₂ 35.9%, CH ₄ 0.4%
HHV, Dry Basis	MI/m ³	11.07
Feed/Oxidant		Bituminous/Oxygen
By Products		Negligible
Utility Requirement ¹		
Oxidant	kg	0.95
Steam	kg	0
Water	kg	N/A
Power	kWh	N/A
Ash Handling		0.41
Thermal Efficiency ²	%	80
Experience		79
Comments		77

Source: Adapted from Mosenko (1987).

¹Per kg moisture and ash free coal.

²Cold gas.

Figure 2
Lurgi Dry Ash Fixed Bed Gasifier
 Source: Simbeck (1983)



The highest temperatures occur here. Additional steam is introduced at this point to control temperature to prevent slagging. As the ash leaves the bed, it releases heat to the incoming oxygen.

In fixed bed gasifiers, the devolatilization products are released from the gasifier at low temperatures as tar and oil which results in the need to remove the tars from the gas at the cleanup stage. The Lurgi gasifier has been used extensively, for example at the Sasol project in the

Republic of South Africa for the manufacture of liquid fuels from coal, and more recently in the Dakota Gasification plant at Beulah, North Dakota, to make substitute natural gas from lignite.

A development of the Lurgi process, the BGL process, which is basically a slagging Lurgi type gasifier, has been under development by the British Gas Corporation. In 1974, a conventional Lurgi 2 m diameter dry ash gasifier was converted to operate in the slagging mode. Oxygen is injected

into the gasifier zone and raises the temperature sufficiently to slag the ash. The advantage is primarily a reduction in steam requirements by up to 15%. By-products such as tars and oils can be recycled to destruction in the gasifier. The produced gas is produced at temperatures in the 450°C range, and is higher in CO than the dry Lurgi process. The process was developed for unreactive bituminous coal and is more suitable for power generation applications than the non-slugging Lurgi process.

The advantages of this process include a high cold gas efficiency, and low oxygen and steam requirements. It also provides the ability to handle caking bituminous coals with substantial fines content.

Fluid Bed

The fluid bed gasifier concept results from the gasifying oxygen or air and steam being introduced to the vessel at a high enough superficial velocity to partially support the weight of the coal particles. This results in the bed behaving as a fluid in maintaining a level surface at the top of the bed and by the appearance of "bubbles" of gas rising through the bed. If the velocity is sufficiently high, the lighter bed material is blown or elutriated from the bed.

The fluid bed is characterized by a nearly constant temperature throughout, and by constant mixing of the coal feed with the partially gasified bed material. Bed temperature is maintained below the initial ash fusion temperature of the ash to avoid clinker formation.

Crushed coal feed can be introduced to the bed either from above or below. Ash is removed by a drain from below the bed. A typical fluid bed system, the KRW process, is shown in Figure 3. Partially consumed coal particles elutriated from the bed are removed from the gas stream by cyclones and returned to the bed. In fluid bed and entrained flow gasifiers, the higher temperatures and a more thorough mixing of the gases result in the decomposition of the devolatilization products to produce hydrogen, carbon monoxide and carbon dioxide.

Several fluid bed processes have been developed. The air blown KRW process was developed initially by Westinghouse for power generations. A central jet, feeding air and coal to

the bed, forms a highly turbulent zone and by rapid devolatilization of the coal, prevents caking of the particles.

An ash agglomeration zone at the base of the fluid bed provides a zone where the temperature is raised to the range where the ash particles become sticky and agglomerate by contact in the turbulent bed. This assists in providing high carbon utilization. As the particles become larger, they drop to the bottom of the bed and, after cooling by recycle gas, are removed by a rotary feeder.

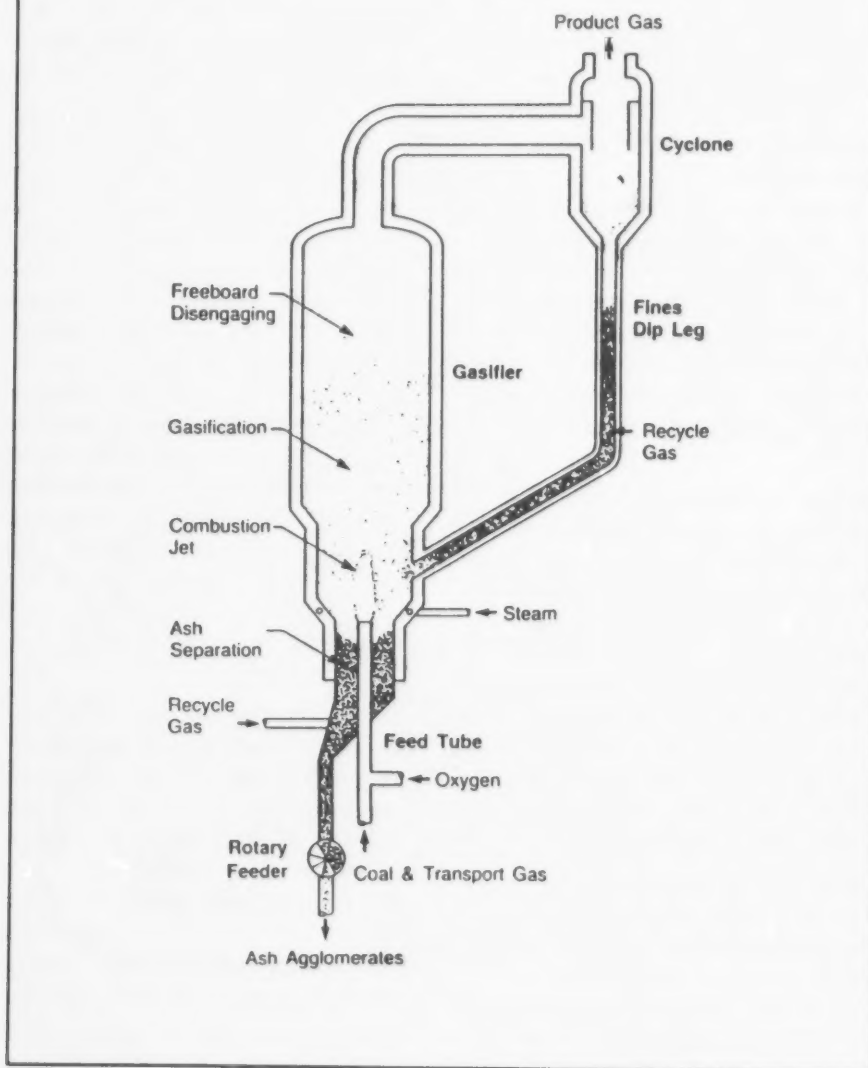
In-bed desulphurization is provided by introducing a calcium based sorbent into the bed, via a lock hopper, where it reacts with the hydrogen sulphide gas to form calcium sulphide. This then falls to the bottom of the gasifier and is removed with the ash for oxidation to calcium sulphate in an external sulphator, generating steam in the process. The spent sorbent is finally disposed of with the ash. Tests have demonstrated up to 90% sulphur removal at Ca/S mole ratios below 2 with high sulphur content Eastern U.S. coal.

Another development the High-Temperature Winkler (HTW) process is being developed by Rheinbraun in Germany for the gasification of lignite and sub-bituminous coals, peat and biomass. It is developed from the atmospheric pressure Winkler process which dates from the 1920s. Development is aimed at IGCC applications and includes operations at up to 25 atmospheres, resulting in a large increase in capacity. The process has a high cold gas efficiency and low generation of sensible heat.

A 700 tonne per day demonstration plant was started up in 1986. This produces a synthesis gas for use in methanol production. In 1989 a pilot plant operating at up to 25 atmospheres began operation. Again, highly reactive German "brown" coal is used, at a rate of 150 tonnes per day. A ceramic particulate filter removal system, operating at up to 400°C removes particulate carried over in the gas. The plant operates either using air or an oxygen steam mixture as the gasifying medium. Tests have been carried out on a large number of coals, including Pittsburgh #8 and a Spanish sub-bituminous coal. Good carbon conversion and cold gas efficiency has been achieved.

A 300 MW IGCC plant is now being designed. The plant will use two gasifiers each fed with 1,800 tons/day of dried lignite. Construction

Figure 3
KRW Fluidized Bed Gasifier
 Source: Simbeck (1983)



is anticipated to start in 1991, with plant start-up in 1995. A 200 MW gas turbine has been selected and the overall plant efficiency is expected to be approximately 43.5%. An interesting design feature of this plant is the use of a vapour recompression heat recovery system with the lignite coal drier. This results in a gain of 2% in cycle efficiency.

Entrained Flow

The entrained flow gasifier is typified by the rapid reaction of finely ground coal with the oxidant and steam in the gasifier. The gasifiers employ single or multiple burners which rapidly gasify the coal at high temperatures in the 2000°C range, producing a gas which contains no tars or oils and is primarily composed of CO, CO₂ and H₂.

Operating temperatures are well above the slagging temperature and this ensures high conversion of the carbon in the coal and provides the ability to gasify all types of coal. The high reaction rates also ensure that output per vessel is high. Entrained flow processes are categorized by the type of coal feed system, the arrangement of the burners, and by the means by which the high temperature gases leaving the gasifier are cooled before the low temperature cleanup stage where the sulphur gases are removed.

Coal, ground to a typical pulverized boiler feed size, is fed to the burner either as a slurry in water or as a dry powder. Processes such as Texaco and Dow use a slurry feed as it provides a simple way of feeding a controlled quantity of fuel to the burner. Other designs, such as Shell, use a dry feed which results in a higher efficiency as there is less heat absorbed in drying the feed coal prior to gasifying.

Burners can be arranged to fire downwards, as in the Texaco process, or upwards as in the case of Shell and Dow. Gas cooling is achieved by radiant and convective boilers in the Texaco case; by dilution with recycled cool, clean gas and then by a convective heat recovery boiler in the Shell case; or by injecting a second stage of coal slurry followed by a convective heat recovery boiler in the Dow case. It should be noted that the Texaco process offers several alternative cooling systems, including a water quench which eliminates the need for waste heat boilers.

Most of the slag produced in the gasifier impinges on the walls of the vessel and flows to the bottom where it drains to a slag tank. Slag entrained in the gas stream is separated from the raw gas before it passes to coolers which are required prior to sulphur removal. The raw gas contains only trace amounts of methane or higher molecular weight compounds.

The presence of molten slag requires that the refractory used in the gasifier be selected carefully to prevent rapid degradation due to erosion and corrosion. Considerable development effort in new gasifier systems is directed at this problem. A typical entrained flow gasifier, the Dow process, is shown in figure 4.

A number of entrained flow processes are well developed and are being commercialized. The entrained flow Texaco gasification process is the

most developed of the pressurized coal gasification processes. In 1977, Ruhr Kohle started up a 165 t/d pilot plant at Oberhausen, W. Germany. This has been used to test a wide range of feedstocks and has allowed the development of a refractory with an operating life of at least two years. In addition to this, development was also carried out on a radiant gas cooler and the new burner giving better carbon conversion.

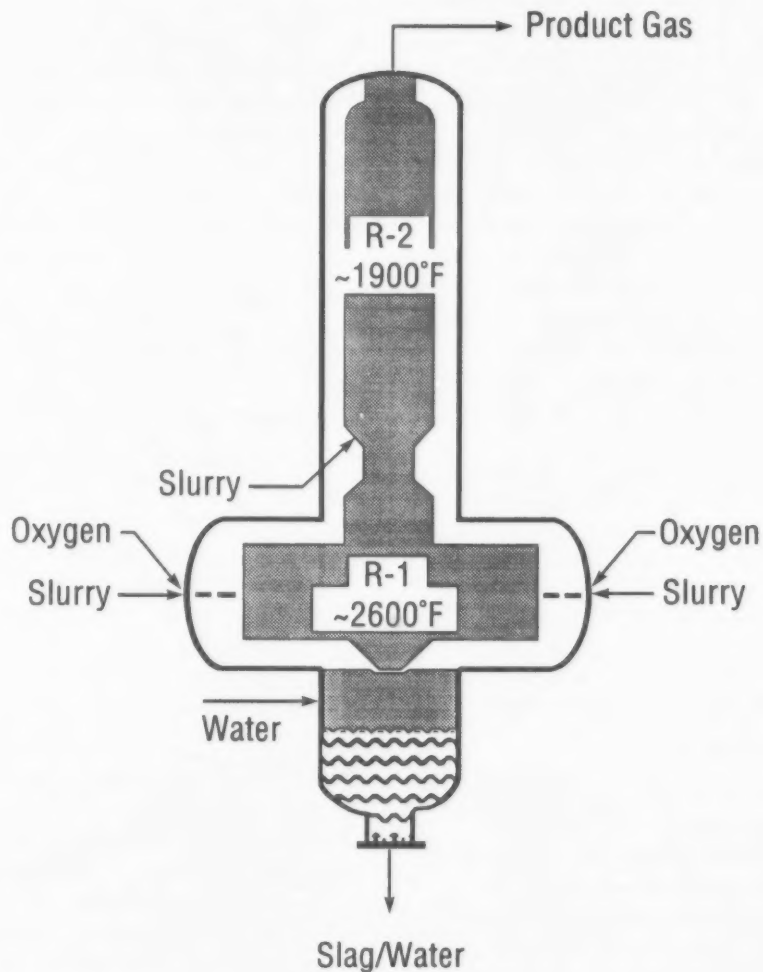
There have been a number of subsequent Texaco gasifier applications such as a demonstration TVA plant at Muscle Shoals, making ammonia; Tennessee Eastman at Kingsport, Tennessee, making acetic anhydride; and at UBE Chemicals in Japan for the manufacture of ammonia. These projects and subsequent development by Texaco have enabled the design to be scaled up to the 1000 t/d level required by the Cool Water project at Daggett, California. This 100 MW demonstration IGCC project was successfully operated from mid 1984 until 1989 when it was shut down, following completion of its planned test schedule. Texaco are now planning to re-open this plant in the near future using a mixture of coal and sewage sludge as a fuel. Recently, a number of other IGCC projects have been announced by Texaco in the United States.

The Dow entrained flow gasification process was developed specifically for low rank coals in IGCC applications. This two-stage process utilizes a pressurized, entrained flow, slagging, slurry fed gasifier. The development has resulted in a continuous slag removal system to eliminate the use of lock hoppers, seen as a high maintenance item, and has a unique heat recovery system which provides high efficiency with high moisture, low rank coals, typical of western Canada.

Dow has now transferred development of this process to its DESTEC subsidiary, which is also responsible for the Plaquemine, Louisiana demonstration plant. This approximately 160 MW IGCC plant was started up in 1987 and includes a gasifier consuming approximately 2,000 tonnes per day of coal, making it the largest single train gasifier in operation.

In the Dow process, a second stage of slurry coal injection is used. This makes use of the high temperature of the gases leaving the first stage to gasify the additional fuel without any further oxygen addition. The coal gas, after cooling and

Figure 4
Dow Entrained Flow Gasifier
 Source: Dow Chemical U.S.A.



cleaning, powers two 100 MW gas turbines which provide on-site power to Dow's process plant, as well as process steam from waste heat boilers. DESTEC has recently announced a commercial IGCC project at Wabash River Unit 1 of Public Service of Indiana. This existing 85 MW steam unit will be repowered, converting it to a 230 MW IGCC plant. Start-up is expected by 1995.

The Shell entrained flow process has a higher cold gas efficiency, a lower oxygen require-

ment, and a lower carbon dioxide fuel gas content than other process. This is due mainly to the dry coal feed system. Among the advantages of the Shell process is its ability to handle a wide range of coal types, from low to high rank coals. Development of the Shell entrained flow gasifier began in the Netherlands in 1972. In 1978, a 165 t/d plant started up at the Shell refinery at Hamburg, West Germany. Since then, a wide range of coal types have been tested.

A pilot plant is presently in operation at the Shell Deer Park facility near Houston, Texas. This first North American demonstration has a feed 250 t/d of bituminous high sulphur coal or approximately 400 t/d of wet, high ash lignite. The plant handles feedstocks with up to 35% moisture, 30% ash, and 4% sulphur. This plant includes coal receiving and preparation facilities, the gasifier, heat recovery, solids removal, and gas and water treatment facilities to provide a clean medium heating value gas and steam for use in the refinery.

The Shell process has been selected for use in the DEMKOLEC project in Holland, the first fully commercial IGCC plant. This plant, which is due to start up in 1993, is rated at 250 MW and has a high cycle efficiency of 41.4 per cent. The Shell process has also been elected as the basis for the feasibility study now being carried out by The Coal Association of Canada as part of a projected demonstration project.

Integrated Gasification Combined Cycle Power Generation

Although coal gasification can be used as a fuel for conventional boilers, its main attraction is in enabling coal to be used in high efficiency power generation technologies – Integrated Gasification Combined Cycle (IGCC) and, in the future, in Integrated Gasification Fuel Cells (IGFC).

IGCC Power Generation

Gas turbines and combined cycle power plants fired by natural gas or light oil are well known to electric utilities. High fuel efficiency, relatively low capital costs, short construction times and rapid response to load following requirements have all been recognized as advantages. Fuel costs (natural gas and distillate) are, however, subject to rapid escalation and have generally been much higher than for coal-fired conventional plants. Coal gasification is the link that has emerged which allows utilities to maintain the flexibility and efficiencies of combined cycle plants yet allows low cost coal to be a part of fuel mix plans.

The IGCC process is shown in schematic form in Figure 5. Ground coal, oxygen from an air separation plant, and steam are fed to a gasifier. The coal is converted at high temperature to a gas, and the slag is removed as a liquid slag. Once

solidified, it is non-leachable and is readily disposed of.

The hot gas is cooled in heat recovery boilers, generating steam. Once cooled, the gas is cleaned of the remaining particulates, sulphur compounds, and other impurities such as ammonia and alkaline metals. The cleaned gas is then reheated and saturated with steam before being fired in a gas turbine, generating electric power. The hot exhaust gases from the turbine are then used to generate additional steam which, together with the steam from the gas cooling stage, generates additional electricity in a steam turbine.

Overall, the process has low emissions of sulphur and nitrogen oxides and the sulphur is removed as a high purity liquid product. By virtue of the high cycle efficiency, carbon dioxide emissions per unit power output can be reduced by up to 20 per cent.

The need to build very large conventional coal plants to take advantage of economies of scale and efficiencies, has, during a period of slow load growth, penalized many utilities having to carry large costs for unneeded generating capacity. The integration of relatively small coal gasifier modules with other existing modular combined cycle plants provide utilities with the building blocks to build large or small plants, coal fired or gas fired, thus improving flexibility and reducing risks.

This has led to the concept of phased construction in which natural gas-fired, simple cycle gas turbine generators are installed in a first phase. The plant can be converted to combined cycle operation by the addition of heat recovery boilers and steam turbines in the second phase. Finally, coal gasifiers, coal and ash handling, and cleanup facilities can be added to provide a clean fuel gas for the gas turbine in the third phase.

What are the disadvantages of IGCC? They include those that are common with most new technologies. The gasifier plant processes are unfamiliar to most utility plant operators. The process is relatively complex and there is limited experience in design, construction and operation. There is a need to continue R & D in the gasification area. Research should concentrate on reducing complexity which will, in turn, reduce cost and increase efficiency, availability and operability.

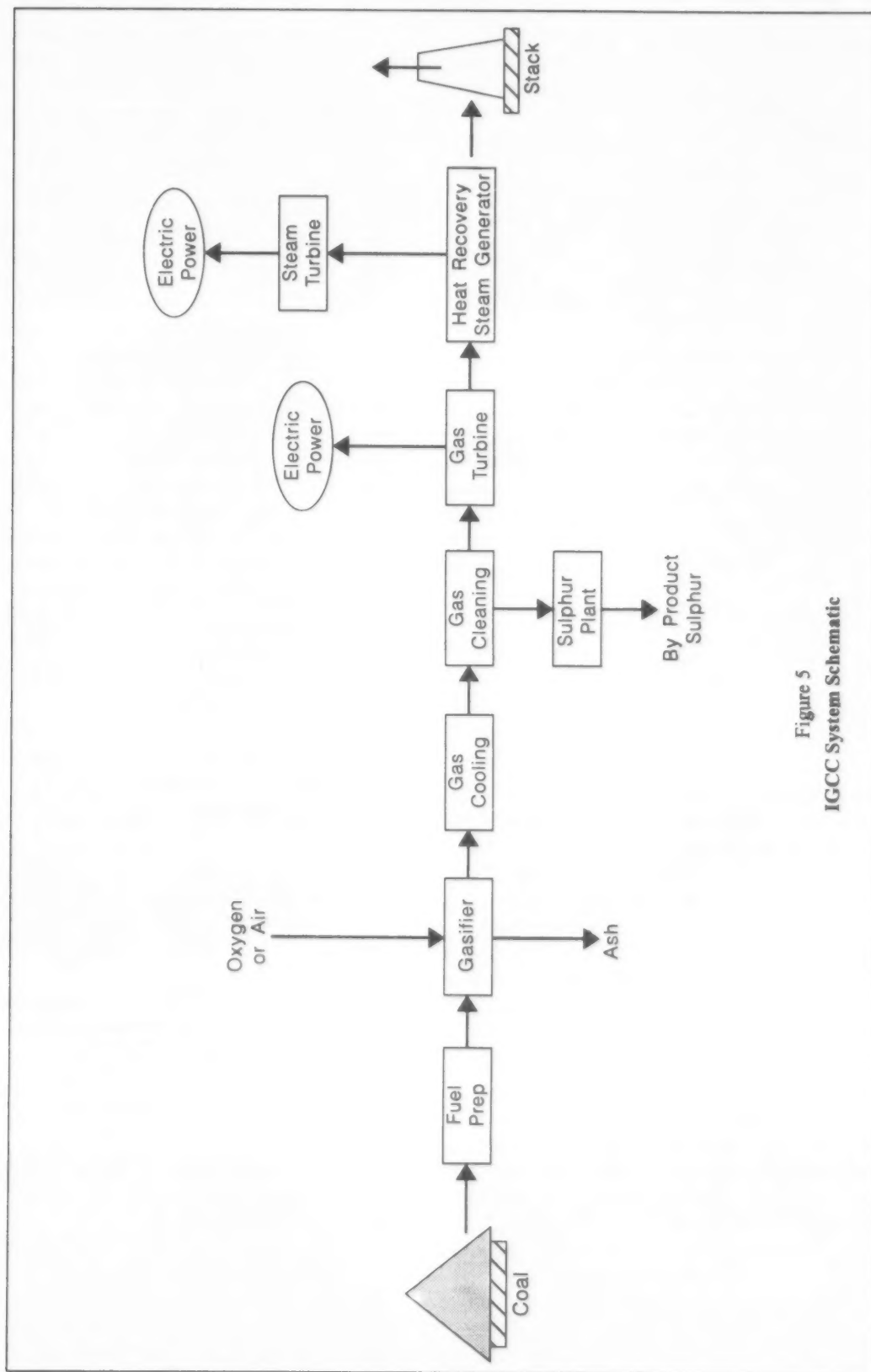


Figure 5
IGCC System Schematic

At present, high temperature raw gas streams must be cooled prior to cleaning. Currently used gas cleanup systems operate at low temperature following the recovery to cool the gas to the 200 – 300°C range when it is scrubbed with water to remove the remaining particulate material. The cooled gas is then sweetened by an amine based process such as the Selexol or Sulfinal processes. These processes, developed for natural gas sweetening, remove the sulphur containing gases H_2S and COS but require that the gas be cooled to temperatures in the 100°C range.

Future systems may use hot gas cleanup systems. These systems will make use of particulate filters such as ceramic barrier filters or granular beds, and sulphur removal systems using zinc ferrite or metal oxides. The object of hot gas cleanup is to enhance cycle efficiency by cooling the fuel gas only as required for the gas turbine fuel system. Current technology limits fuel gas temperatures to around 550°C because of the limits imposed by fuel control and metering systems. Hence, gas produced at higher temperatures must be cooled to some extent before it can be fired. It is anticipated that the use of hot gas cleanup systems could improve cycle efficiency by up to 4% or 5%.

The Coal Association of Canada IGCC Project

To address the environmental concerns related to coal, The Coal Association has initiated an IGCC demonstration project with the support of many of Canada's electric utilities and coal supply companies who are committed to accelerating the introduction of this clean coal technology in Canada. The Coal Association's IGCC demonstration project has the goal of designing and building a commercially sized IGCC power plant in Canada to demonstrate the viability of such a plant under the conditions unique to Canada, such as using Canadian coals, and under severe winter conditions.

The Coal Association's IGCC demonstration project will be carried out over a five-year schedule starting with a feasibility study and selection of a site. This process is now under way. The project will be carried out in three phases: Phase 1 consists of a technical feasibility study, Phase 2 consists of detailed design and cost estimation, and Phase 3 consists of construction and operation. Phase 1 is being supported financially by many of the member organizations of The

Coal Association of Canada, including five electric utilities. Support has also been obtained from both the federal and provincial governments under the Western Low-Sulphur Coal to Ontario program and the Province of British Columbia.

The feasibility study, which will require approximately a year to complete, is now under way. It consists of two stages. Stage 1 will determine an appropriate site in Alberta or Saskatchewan. Discussions on site selection have shown that there are several promising sites in Alberta and Saskatchewan. Final selection of a site will depend on the outcome of the feasibility study and on more detailed assessments of the requirements for additional power by the electric utilities involved. Stage 2 is the conceptual design and cost estimates. It includes selection of the gasification process, selection of a gas turbine, design of the gasification and gas clean-up systems, and design of the combined cycle power plant. Plant cost estimates will be an important output from the study.

Some major decisions have been made in relation to the plant design. The Shell gasification process has been selected as a basis. The other major piece of equipment to be selected is the gas turbine. The General Electric 7F advanced gas turbine will be the basis of the design. The turbine is rated at approximately 170 megawatts for this application site and design temperature.

The basis of the feasibility study is a prairie mine mouth plant site, similar to TransAlta's Keephills plant, using coal from TransAlta's Highvale Mine, west of Edmonton. Besides the base case, sensitivities cases will be evaluated for Saskatchewan lignite and a B.C. bituminous coal. Two other cases are also being evaluated: a remote gasifier providing clean gas by pipeline to an existing power plant located in Edmonton, and a variation of the base case in which 50 per cent of the carbon dioxide produced will be recovered as a source for enhanced oil recovery.

It is anticipated that acid gas emissions from the plant will be reduced to very low levels, with sulphur captures of 98 per cent expected. The plant efficiency will be significantly greater than for a conventional coal fired plant, particularly given the low level of emissions. This has the benefit of reducing the carbon dioxide emissions per unit of electrical output. It is hoped that the

study will lead to the detailed design stage and result in an early Canadian demonstration of this promising clean coal technology.

Co-Production of Electric Power and Chemicals

When coal is gasified with oxygen, the raw gas contains principally hydrogen and carbon monoxide, with smaller amounts of carbon dioxide, hydrogen sulphide, ammonia and nitrogen. This synthesis gas can be used for the co-production of chemicals to enhance the economics of the plant.

There are two alternatives which can be considered. The first is to co-produce a liquid or gaseous fuel which can be used to supplement the fuel to the gas turbines for peaking use or when the gasification plant output is reduced due to equipment outage. The second is to co-produce a chemical for export from the site on a continuous or intermittent basis.

With IGCC plants, the gas turbines are capable of firing at higher rates during winter because of the larger mass flow of air at colder temperatures. This results in an imbalance in capacities of the gasification facilities and the power generation facilities. Either the gasification plant can be designed to load the gas turbines fully in winter, in which case extra gasification capacity will exist during the summer, or the gasification plant can be designed for summer gas turbine capacity, which requires supplemental fuel in winter to attain full output.

Production of a supplementary fuel such as hydrogen or methanol can be used to overcome this problem. The liquid fuel, methanol, makes storage more simple, although hydrogen can be stored under pressure to level output over the daily cycle. A useful study on this subject was undertaken by EPRI and Florida Power and Light Company and is described by Walters (1990). This reviews the co-production of methanol in an IGCC plant.

Co-production of chemicals for export could include hydrogen, carbon dioxide, methanol, ammonia, urea or a range of other products. It could also include the export of synthesis gas to a utilization facility "across the fence". TransAlta Utilities has co-funded studies for plants based in Alberta co-producing CO₂ and hydrogen in one case, and methanol in another. The results of these

studies showed, as expected, that the advantages of co-production are very much dependent on the value of the co-produced chemicals.

This is in agreement with studies conducted by EPRI (Gluckman, 1988) which showed the advantages of producing a high valued product such as gasoline. For a base of 400 MW IGCC plant operating at 65% capacity burning coal costing \$1.66 U.S./million Btu, the 30 year levelized cost of power is about 5.3 ¢ U.S./KWh (1987\$). If the gasification plant runs at an additional 25% capacity (for a total of 90% - already achieved by Ube Chemicals in Japan) and if 50% of the coal feed is converted to a high value product at \$200 U.S./ton, then the cost of electricity can be reduced to 3.5 ¢ U.S./kWh or a reduction of 34% from the base case.

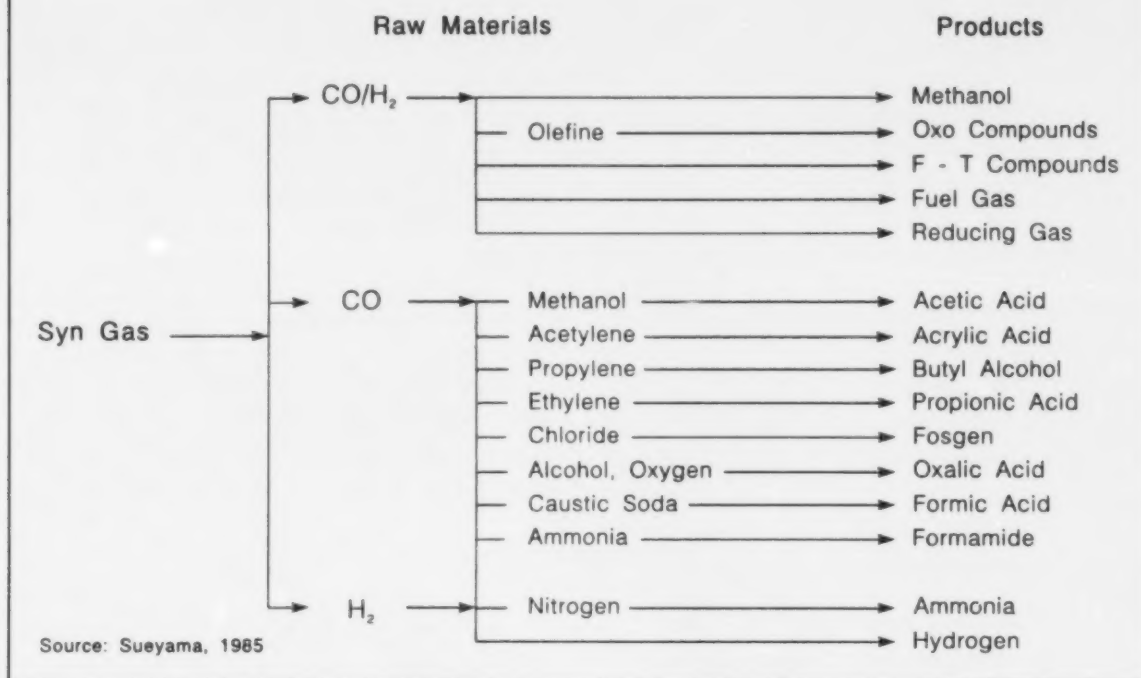
Coal gasification provides a starting point for a range of chemicals and a number of projects are in operation. Texaco gasification is used by Tennessee Eastman to make 700 t/d of acetic anhydride and by Ube Industries to make 1,000 t/d of ammonia. Two further plants in Germany produce syn gas for the production of oxy-chemicals (Texaco) and methanol (H. T. Winkler). Figure 6 shows possible routes to chemical production as developed by Ube Chemicals in Japan (Sueyama, 1985).

Advanced Hybrid Cycles

As mentioned above, PFBC cycles have a gas turbine inlet temperature which is set by the bed temperature. It has been proposed, by British Coal among others, that one way to get round this limitation is to introduce a pyrolysis or partial gasification step in which the coal is tripped of the volatile components to produce a fuel gas. The residual char is fed to the PFBC as before, and the fuel gas is then fired in a combustor in the gas turbine before expansion in the turbine. One process layout is shown in Figure 7. (British Coal, 1989)

A similar process has been proposed by IGCC developers. The option of using air, rather than oxygen, as the oxidant eliminates the large power consuming air separation plant. However, air blown gasifiers may have difficulty in achieving a sufficiently high carbon conversion and to complete the utilization of the fuel, a PFBC combustor can be used. The resulting cycle is then

Figure 6
Chemical Products From Syn Gas



in essence the same as that described above.

The main variable in question is the proportion of the coal input energy which is converted to gas, and which is released in the PFBC. In general, the higher the proportion which is converted to gas, the higher the theoretical cycle efficiency.

These processes are under development by British Coal. Performance estimates indicate high efficiencies in the 40 to 45 per cent range.

Integrated Gasification Fuel Cells (IGFC)

The technology of fuel cells is rapidly advancing in the United States and Japan. A number of competing fuel cell technologies are being developed, with the two most advanced - molten carbonate and solid oxide - being capable of accepting the fuel gas from coal gasification as a feed stock.

A major R & D program is under way in the United States (Fuel Cell Seminar, 1990). The three major funding organizations supporting fuel cell development are the Department of Energy

(DOE), the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI). The overall goals of these organizations are:

- To support the development of promising fuel cell systems;
- Fund basic and applied research to provide the technology foundation for the development of fuel cell systems;
- Support the development of new fuel cell concept that potentially offer improved performance and cost; and
- Expedite the application of these technologies by assisting private sector developers in activities related to the commercialization of fuel cell systems.

All major types of fuel cells are being supported with multi-developers for each technology to provide the competitive incentive to produce better products. Up to the present time, approximately one billion dollars has been spent on fuel cell developments in the United States.

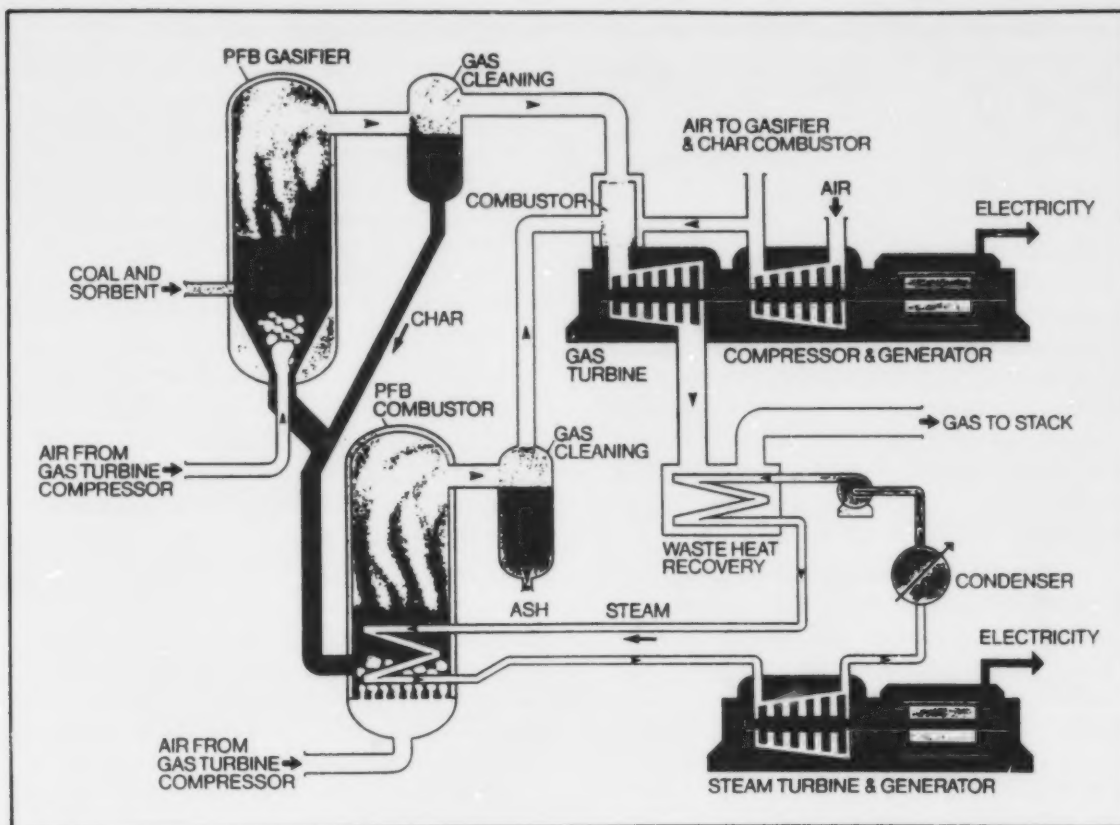


Figure 7
British Coal Topping Cycle Flow Diagram
Source: British Coal

The DOE is supporting technology development of phosphoric acid fuel cells (PAFC), molten carbonate fuel cells (MCFC) and solid oxide fuel cells (SOFC) for application in electric utility, commercial/residential and industrial markets, with the eventual aim of developing coal based systems. The GRI efforts are focused on the use of natural gas for application in the commercial sector but with an eventual development of small residential sized units. EPRI is supporting fuel cell development leading to the introduction of modular electric utility fuel cell power plants that are efficient, environmentally acceptable, cost effective, and able to use a variety of petroleum and coal-derived fuels. They also support commercialization demonstrations involving international efforts.

Molten carbonate fuel cells are a good candidate for use with coal gas containing hydrogen, carbon monoxide and carbon dioxide. This

cell design uses molten lithium and potassium carbonates as an electrolyte and operates at relatively high temperatures in the 550°C to 750°C range. Electrodes are made of nickel and nickel oxide. Gas from the anode contains a proportion of unreacted hydrogen and is recycled back to the fuel gas stream. Gas from the cathode, containing carbon dioxide, is recycled back to the cathode to provide the carbon dioxide necessary to maintain the carbonate. Both of these features result in higher cell efficiency.

While this technology has achieved stacks of cells of only 100 kW at the present time, Energy Research Corporation, a major developer, has ambitious plans to scale up to 2 MW size within five years. A 20 kW stack is to be tested with coal gas as a fuel in tests to be conducted at the Dow gasification plant at Plaquemine, Louisiana later this year.

The solid oxide fuel cell is a high temperature fuel cell which has been under development for over 20 years by Westinghouse and the ABB. The cell is comprised of a dense electrolyte layer sandwiched between a porous air electrode and a porous fuel electrode. A fourth layer carries electrons from the fuel electrode of one cell to the air electrode of the next cell.

Advantages claimed for the SOFC include the ability to reform hydrocarbons directly in the fuel cell because of the high operating temperature, thus eliminating the need for a separate reformer and the ability to accept CO, CO₂ and a range of impurities and variations in fuel composition. A higher system efficiency may be possible with this type of cell, and the waste heat is of a high enough quality to be used in a bottoming cycle.

Westinghouse has been an early leader in the development of this type of cell. A tubular design has been developed with the help of the DOE and tests of individual cells have now exceeded two years continuous operation, with generator tests of 6,000 hours using natural gas fuel. A 20 kW cell is now being developed and design requirements for 20 MW and larger coal gas fueled power plants are being established. Westinghouse's program has focused on the use of coal derived fuel gas for large scale power production.

In the future, fuel cells operating on coal gas may offer the highest efficiency and cleanest coal based power generation option. Estimates of the performance which might be achieved by advanced IFGC plants based on this technology show efficiencies over 50 per cent with almost no emissions of SO₂ and NO_x.

Magnetohydrodynamics (MHD)

Magnetohydrodynamics (MHD) is a high temperature, clean power generation technology which generates electricity directly by the passage of a conducting, high velocity gas stream through a magnetic field.

Coal is burned at high temperature fuel rich conditions in a pressurized combustor to produce a gas at around 2650°C. An electrically conducting salt such as a potassium based compound is added to the gas as a "seed" and, after expanding to high velocity through a nozzle, it

passes through a magnetic field produced by superconducting magnets, generating D.C. power directly. The hot exhaust gas, now cooled to around 1900°C, is then used to generate steam in a heat recovery steam generator, and additional electricity in a conventional power cycle. The seed salt is then recovered from the gas and regenerated for re-use, and sulphur captured by the seed salt from the combustion gas is removed along with particulate matter. A typical flow diagram is shown on Figure 8 (Walter, 1989). This combined cycle MHD design is projected to have an efficiency of 50 to 60 per cent.

Emissions from the plant will be low as the potassium salt will capture essentially all the sulphur as potassium sulphate. NO_x is controlled in the steam generator and is expected to reduce emissions to around 80 ng/J of energy input.

Needless to say, given the extremely high temperatures that occur in the cycle, considerable development work is required before MHD can approach the demonstration stage. In the United States, the DOE has been supporting development and has a 50 MW_{th} coal fired MHD power train in operation since 1985. Testing of this unit will include ten 100 hr rounds to confirm combustor and channel durability.

Development plans are in place to carry out a demonstration project which will be a retrofit of an existing plant in the 100 MW range. It is hoped that the technology can be demonstrated and commercialized by the year 2000, or shortly thereafter.

Direct Coal Fired Gas Turbines

A final advanced technology which has been proposed and tried several times over the past 60 years is the direct coal fired gas turbine. Earlier attempts at direct coal firing have approached the problem by attempting to make the turbine survive in the coal fired gas environment and while this has shown that the turbines will definitely operate, they will not operate indefinitely.

Current development in the United States by the DOE is focused on the combustor. Two approaches have been tried. In one, ultra-clean coal is prepared as a coal-water fuel and burned in a modified combustor. The low levels of ash and sulphur have improved the durability of the turbine, but as this is still dependent on turbine

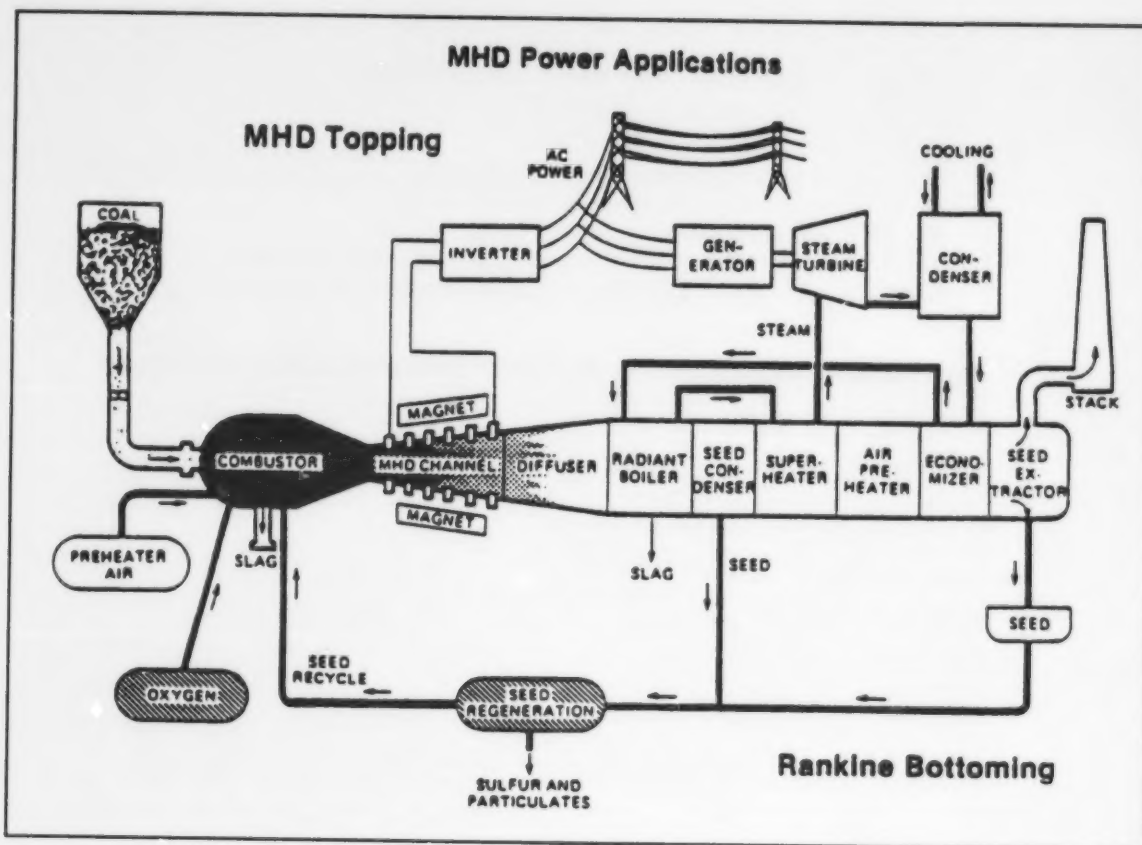


Figure 8
MHD Power Cycle Schematic
Source: Walters, 1989

inlet temperatures, it operates at a lower turbine inlet temperature, thus limiting the efficiency.

A more promising approach is to develop an advanced combustor system which captures the sulphur in the flue gas and causes the ash to slag and be removed as a liquid, with the remaining particulates being removed by high temperature filtration. Solar Turbines and others are working on this approach.

A further technology which could be used is TransAlta's LNS Burner which has demonstrated its ability to reduce sulphur and NO_x emissions to very low levels simultaneously and removes up to 80 per cent of the ash as a slag.

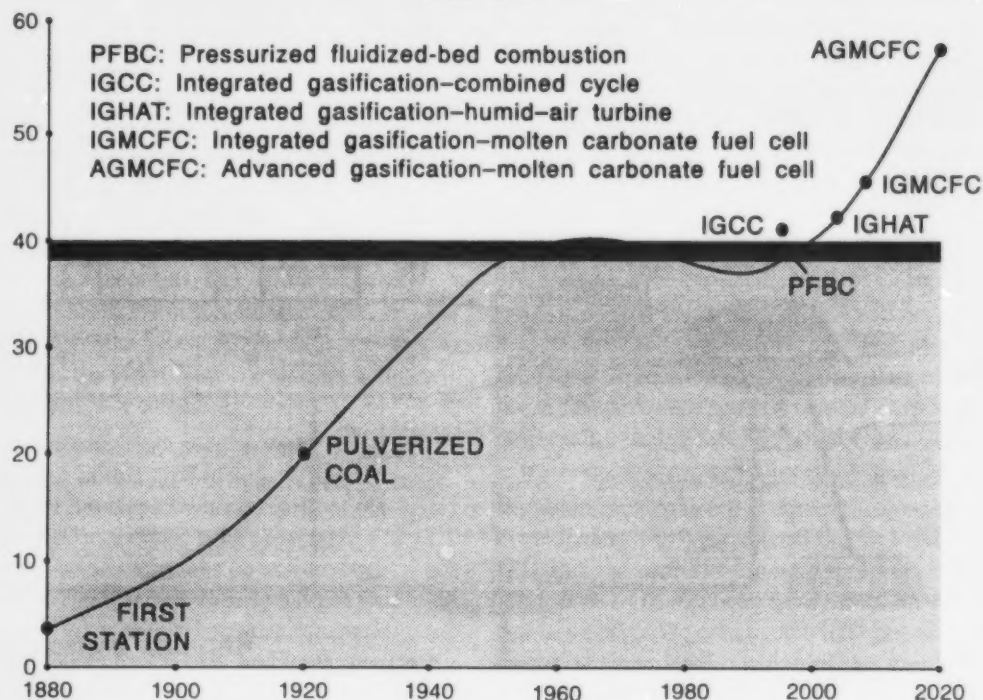
Should present work be successful, a highly efficient coal fired gas turbine combined cycle power plant would result, having efficiencies

in the 45 to 48 per cent or higher depending on the turbine inlet temperature achieved. Emission of SO_2 and NO_x will be low, perhaps not as low as IGCC but with a much simpler plant, costs could be significantly lower.

Comparison of Advanced Power Generation Cycles

As can be appreciated, assessment of the variety of the potential advanced clean coal technologies is not a straight forward task and can be easily influenced by the assumptions made. The Electric Power Research Institute has attempted to do this and shows that efficiencies in the 60 per cent range using advanced gasification and molten carbonate fuel cells may be achieved by 2020. (Douglas, 1990) (Figure 9) Other comparative studies have shown that the excellent environmental benefits of IGCC offset the higher costs, as

Figure 9
Coal Fired Power Plant Efficiency Projection
Source: EPRI



compared to PFBC, by reducing solid waste disposal problems as well as gaseous emissions.

Within the Canadian Electrical Association, a project is being initiated to assess a variety of advanced power generation cycles on an equal basis using typical eastern and western coals as a basis. This state of the art assessment will be used to direct R & D efforts over the next few years.

Coal is, and will for the foreseeable future, be an important fuel source for the generation of electricity in Canada and around the world. Questions raised in regard to emissions of sulphur dioxide, oxides of nitrogen, and more recently of carbon dioxide, must be addressed before this fact will be accepted by the general public.

Coal gasification and IGCC are technologies which provide electric utilities with many advantages over conventional power generation. Reduced water needs, faster construction times and smaller economic plant sizes are all important, but

major reductions in the emissions of sulphur dioxide and NO_x are likely to be the most important considerations.

The promise of higher efficiency combined with a reduction in other environmental impacts is making IGCC coal based technology of choice for many utilities in North America and overseas. Future development of advanced fuel cells will reinforce this trend and enable significant reductions in per unit CO_2 emissions to be made.

Sulphur and nitrogen oxide emissions, already shown in Germany and Japan to having been reduced by 75 to 80 per cent by existing technology, can be reduced close to zero. By introducing more efficient power generation cycles, unit carbon dioxide emissions will potentially be reduced by up to 40 per cent relative to typical current carbon dioxide emissions. These technologies will be approaching commercial use by the late 1990s, and be in use by 2020.

APPENDIX C.



Appendix C. THE COALFIELDS OF BRITISH COLUMBIA

Coalfields of British Columbia contain large volumes of coals ranking from lignite to anthracite. These coals range in age from Jurassic to Tertiary. Coals are found in virtually all sedimentary basins in the province and occupy a wide variety of geographic regions.

To date the major exploration emphasis has been on the delineation of coking coals for the export market. This concentration of effort has tended to overshadow the fact that British Columbia possesses large resources of thermal quality coal. As quality requirements change non-coking coals will receive increasing attention.

The coalfields of the province are located in three major tectonic zones; Rocky Mountain, Intermontane and Insular. The Rocky Mountain zone contains those coalfields in the Rocky Mountains in southeastern British Columbia (East Kootenay Coalfields) and the Rocky Mountain Foothills in northeastern British Columbia (Peace River Coalfield). The Intermontane zone is a broad zone laying between the Insular zone and the Rocky Mountains. The Insular zone is the westernmost of the three northerly trending belts and it contains a narrow strip along the Pacific Ocean.

The Rocky Mountain zone contains the coalfields of northeastern and southeastern British Columbia. It is this zone which is the most active, containing all but one of the province's coal mines. The coals from this region are dominantly bituminous in rank and are used to make coke. Thermal coal from this region is usually weathered metallurgical coal. Some weak coking coals are also sold from this region. The coals of major interest are Jurassic and Cretaceous in age.

The Intermontane zone contains coalfields ranging in age from Jurassic to Tertiary and they vary in rank from lignite to anthracite. Coalfield

and individual deposit size range from small to extremely large. The vast majority of the coals from this zone are of thermal coal quality. Some deposits such as Telkwa would make an excellent export thermal coal while others such as the Hat Creek deposit are more suited for mine mouth power generation. Many of the coalfields in the northern part of this zone lack the required infrastructure to make them of immediate economic interest.

The Insular zone includes deposits on Vancouver Island and the Queen Charlotte Islands. The coalfields are Jurassic to Tertiary in age and these coals range from lignite to anthracite in rank. Most of the coal is high volatile bituminous with the high rank coals such as anthracite resulting from heating due to igneous intrusions. The Vancouver Island coalfields have produced significant tonnages in the past but at present only one mine is active. The coal resources of the Queen Charlotte Islands are described in conjunction with the deposits of the northern Intermontane zone in this report due to their northern setting.

The coal resources documented here are only those coals which occur within a specific distance of the ground surface. This distance will vary from area to area but the implication is that a coal is considered a resource only if it can conceivably be accessed for extraction. Extremely large amounts of coal occur at depths too deep to be considered coal resources. Below the plains of northeast B.C. is an example of this type of coal occurrence. These coals may still be of economic importance but not in the traditional sense.

The following table illustrates the resource base of immediate interest in British Columbia. At the present an annual production rate, of about 30 million tonnes this is obviously a long term resource base.

Table 1.				
Rank	Measured	Indicated	Inferred	Total
	(million tonnes)			
lvb-an	100	500	1010	1610
m-lvb	1015	2285	5970	9270
h-mvb	1435	1445	4310	7190
sub-hvb	45	160	440	645
lig-sub	450	320	320	1090
total	3045	4710	12050	

The following sections further describe the individual deposits and coalfields in these tectonic zones. Only a brief quality description is given for these deposits as detailed quality descriptions are obtainable in other Ministry of Energy, Mines and Petroleum Resources publications. In summary the province has large resources of all major coal types and its ability to participate in the world coal market will not be controlled by a lack of coal resources.

ROCKY MOUNTAIN ZONE

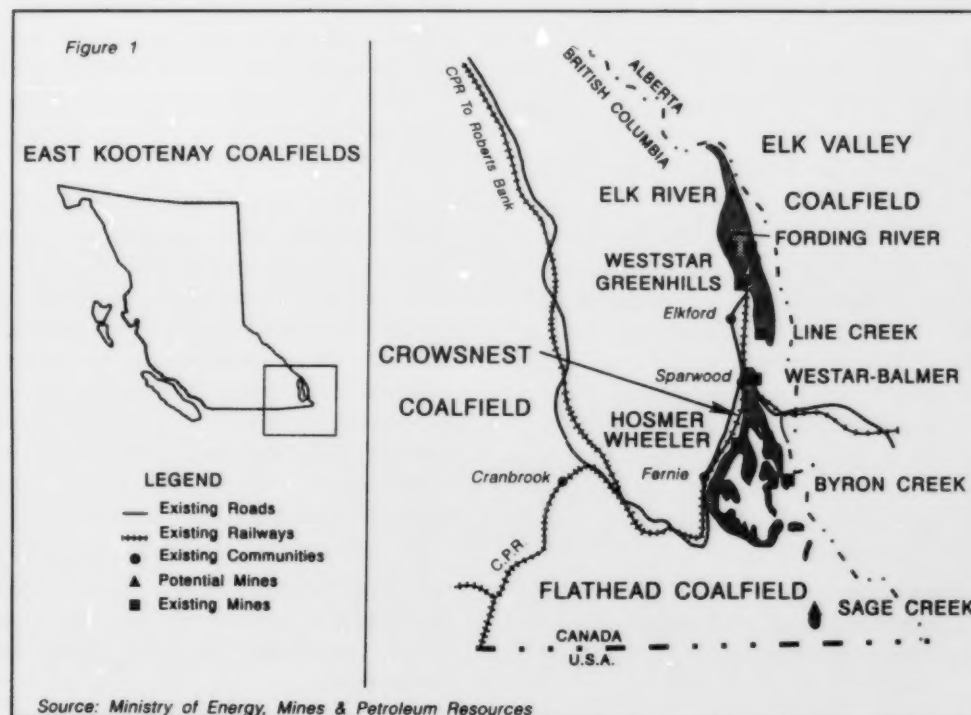
EAST KOOTENAY COALFIELDS

Location and Definition

The East Kootenay coalfields, or the East Kootenay Coal District (Smith, 1989), are located in southeastern British Columbia, near the Alberta and Montana borders (Figure 1). They are geologically related to the Crowsnest, Cascade and Panther River-Clearwater coal districts in southwestern Alberta (Smith, 1989). Three structurally separate coalfields comprise the East Kootenay coalfields (Figure 1). They are, from north to south, the Elk Valley, Crowsnest (or Fernie Basin) and Flathead coalfields. Three active mines, the Fording River, Greenhills and Line Creek operations are all within the Elk Valley coalfield, while two mines, the Balmer and Byron Creek Collieries operations, are in the Crowsnest coalfield (Figure 1).

Geology

The East Kootenay coalfields are part of the Front Ranges of the southern Canadian Rocky Mountains. They are located within the Lewis



thrust sheet, a geological domain characterized by extensive faulting and folding. The important coal seams belong to the Mist Mountain Formation of the Jurassic-Cretaceous Kootenay Group, and there are generally several potentially economic seams at any location (Figure 2). Seam correlation is not established, and coal seam names apply only to local areas.

Resources

Coal resources in the East Kootenay coalfields are summarized in Table 2. In many cases resource data are confidential, and so they are not provided on a property-by-property basis. A large number of properties are present in the three coalfields of southeastern British Columbia. Their names and the level of development is outlined in Table 3.

Table 2			
Compilation of Resources of Immediate Interest (from Smith, 1989)			
Coalfield	Measured	Indicated	Inferred
(millions of tonnes)			
Elk Valley	600	850	2 800
Crowsnest	700	300	1 000
Flathead	70	150	200
Totals	1370	1300	4000

Total resources of immediate interest, in the measured, indicated and inferred categories, are in excess of 6.7 billion tonnes. Total resources of immediate and future interest are believed to be approximately 13.5 billion tonnes. As a general rule, about 85 per cent of these totals can be considered to have potential for metallurgical use. The remainder has potential for thermal use only; all potential metallurgical coal also makes good thermal coal.

Reserves

Producing properties

It is difficult to compare coal reserve figures between different properties because of inconsistencies in methods of reporting. The figures below can be considered, however, to be a good general indication of the size of the reserves at each location. Values at each site represent

Table 3		
SOUTHEAST COAL PROPERTIES INCLUDED IN RESOURCE CALCULATION		
Key	Property	Level of exploration*
Elk Valley coalfield		
1	Bare Mtn	2
2	Burnt Ridge	3
3	Burnt Ridge Extension	3
4	Chauncey Ridge	1
5	Crown Mtn.	2
6	Elk River	5
7	Ewin Creek	3
8	Ewin Pass	4
9	Fording River	7
10	Greenhills	7
11	Horseshoe Ridge	4
12	Line Creek/Line Ck. Extension	7
13	Mt. Banner	2
14	Mt. Michael	1
15	Tee Pee Mtn.	2
Crowsnest coalfield		
16	Balmer	7
17	Byron Creek	7
18	Corbin (Coal Mountain)	4
19	Dominion Coal Block:	
	Parcel 73	3
	Parcel 82:	
20	Flathead Ridge	4
21	Mt. Taylor	1
22	Hosmer-Wheeler	5
23	Leach Creek	1
24	Lodgepole	3
25	Marten Creek	2
26	Marten Ridge	3
27	McEvoy Creek	1
28	McGillivray	3
* EXPLANATION OF CODE NUMBERS FOR LEVEL OF EXPLORATION		
1:	Preliminary geological assessment.	
2:	Minor exploration including some drilling &/ or bulk sampling.	
3:	Major exploration including drilling &/or bulk sampling.	
4:	Advanced exploration &/or feasibility study.	
5:	Stage 2 report for proposed mine development submitted	
6:	Past producer.	
7:	Producer.	

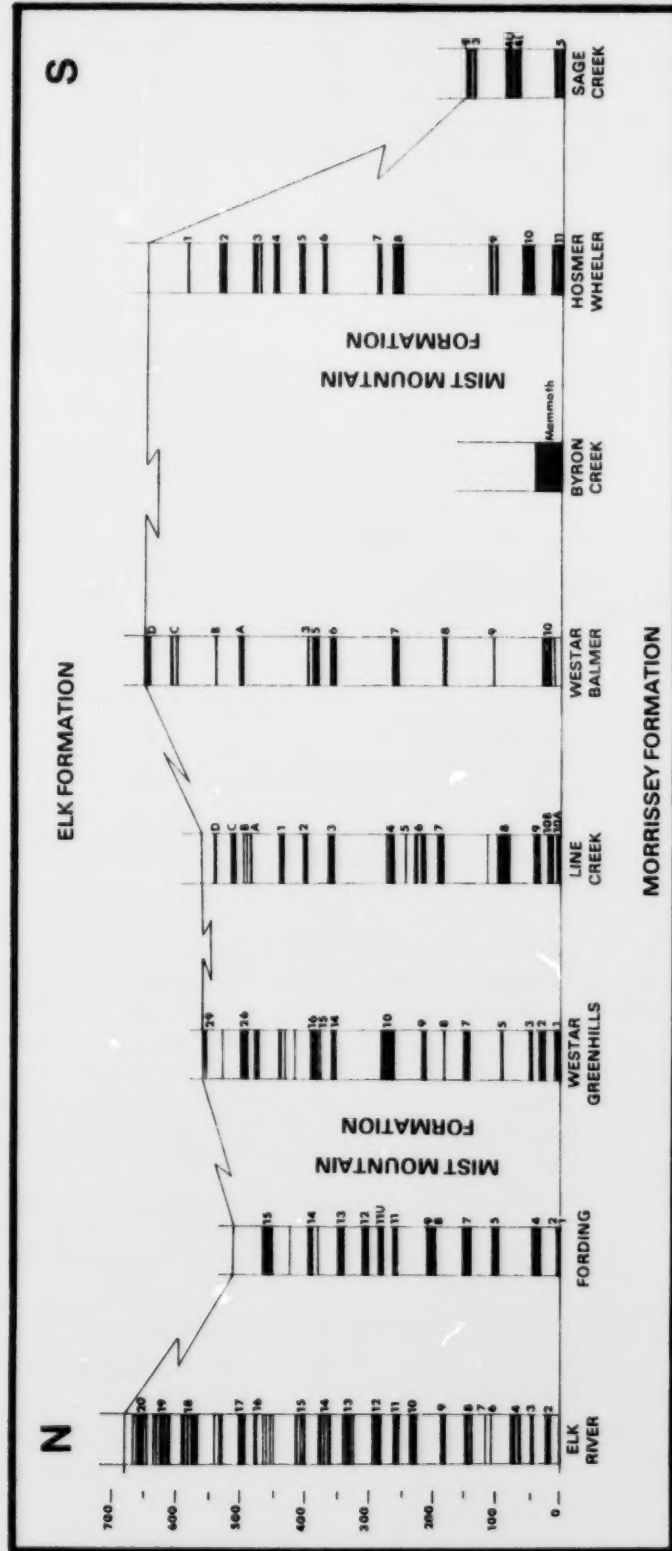


Figure 2: Mist Mountain Formation, stratigraphic schematic.

proven reserves, with the exception of the Fording River operation, where the number cited represents proven and probable reserves. All data were obtained directly from the mining companies, and are reproduced here from Ministry of E,M&PR Preliminary Map 65 (1991 version). Mine locations are shown in Figure 1 and schematic stratigraphic sections are shown in Figure 2.

Fording River	- 350 million tonnes.
Greenhills	- 100 million tonnes.
Line Creek	- 50 million tonnes metallurgical; - 19 million tonnes thermal.
Balmer	- 300 million tonnes.
Byron Creek	- 93 million tonnes (weak coking and thermal).

Non-producing properties

Values of measured reserves for individual properties have been derived from various sources, but mainly represent in-place reserves. The main criterion for including each of the inactive properties summarized here was the existence of a Stage 2 report, submitted for approval of mine development. Again, these values are intended to give only a rough indication, and direct comparisons between properties are not recommended.

Sage Creek - Mineable reserves in the Sage Creek property, near the Montana border in the Flathead coalfield, are 55.6 million tonnes. It is all medium-volatile, thermal coal, and is surface mineable. Weak coking coal is also expected to be a product from this property; at the time that the property was evaluated there was no market for Western Canadian weak coking coal. (N.B. - A decision handed down by the International Joint Commission may have in effect sterilized the Sage Creek and other coal deposits by disallowing coal mining in the watershed of the Flathead River.)

Hosmer Wheeler - Mineable reserves of 60 million tonnes of metallurgical coal were located in the Hosmer-Wheeler property in the Crowsnest coalfield. The coal is of medium and high-volatile rank, and is underground mineable.

Elk River (Little Weary Ridge) - The proposed Elco mine-site on the Elk River in the Elk Valley coalfield contains 225 million tonnes of surface-mineable, medium and low-volatile coking coal.

Coal Quality

Rank

Figures 3 and 4 show surface coal rank distributions based on petrography in the Crowsnest and Elk Valley coalfields, respectively. Coal rank in the East Kootenay coalfields ranges from high volatile A bituminous up to low volatile bituminous, with ranks most commonly in the medium volatile range. There is a strong suggestion that semianthracite occurs at depth in the south-central part of the Crowsnest coalfield, but this is as yet unproven. At one location in the Elk Valley coalfield high volatile B bituminous coals have been found. Ranks of individual seams can vary from one major fault block to another, and in the case of the Crowsnest coalfield ranks have been shown to increase with loss in elevation (down dip). The typical situation has medium-volatile

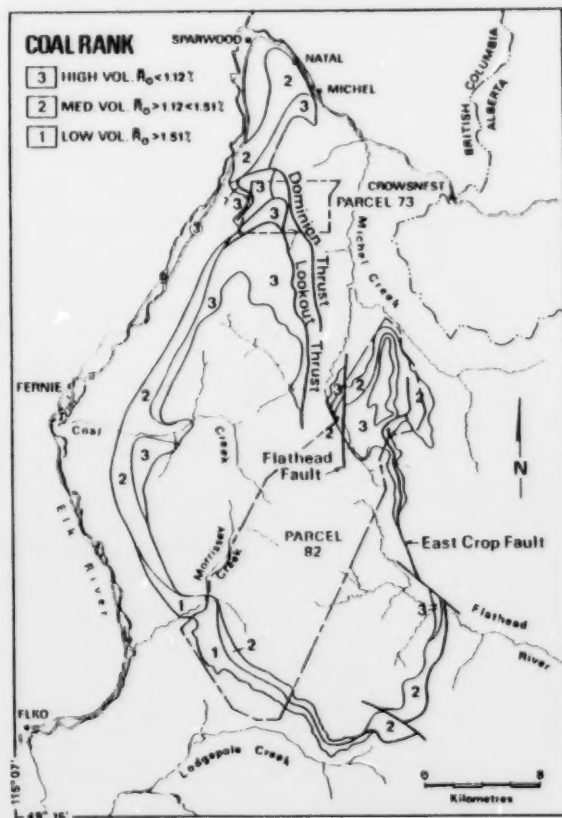
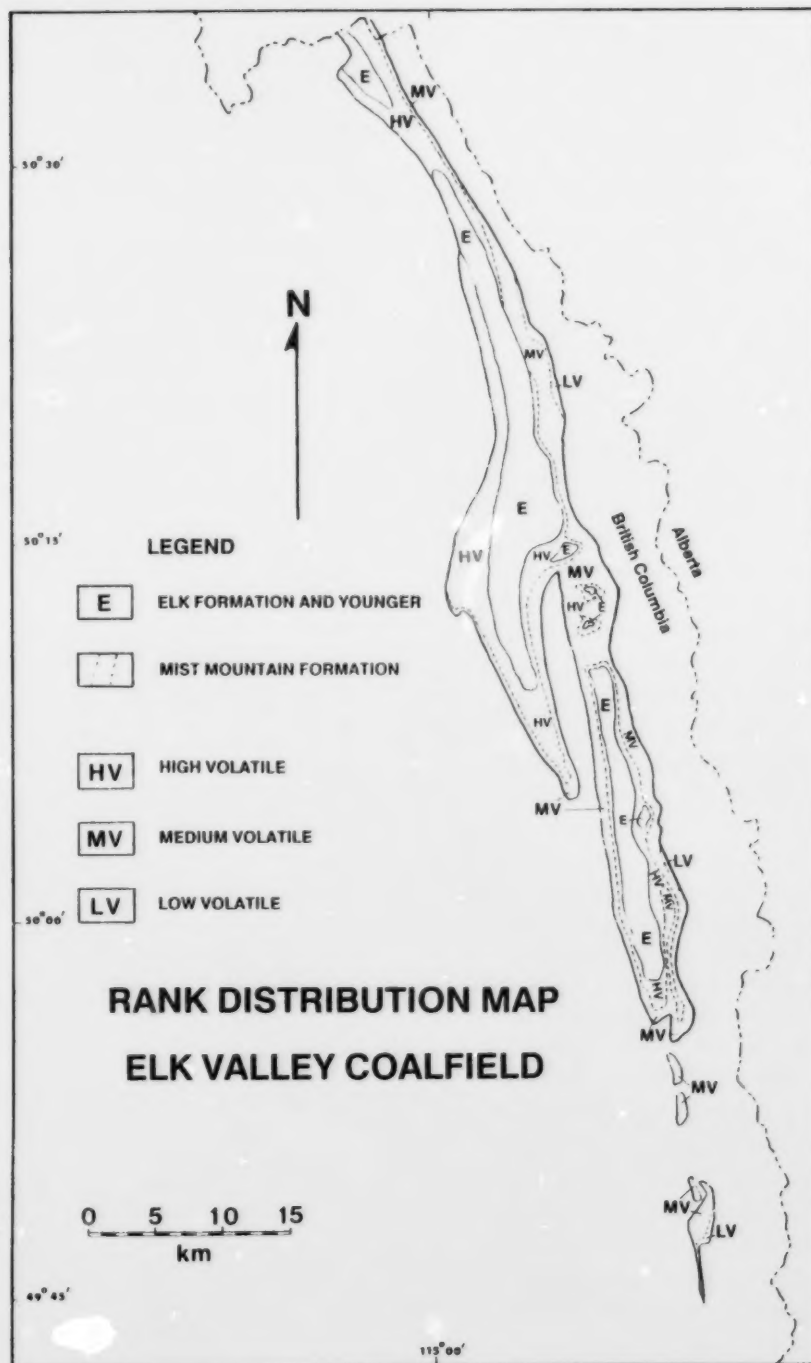


Figure 3: Distribution of coal rank in Crowsnest coalfield, based on reflectance values of grab samples of coal collected in the field (from Pearson and Grieve, 1985).

Figure 4



coals, with reflectances ranging from 1.20 to 1.45 per cent, at the base of the formation, and with high volatile A bituminous coals, with reflectances of 0.8 to 1.0 per cent, at the top of the formation. In the Flathead coalfield, however, where the formation is much thinner, almost all coals are medium volatile in rank.

PEACE RIVER COALFIELD

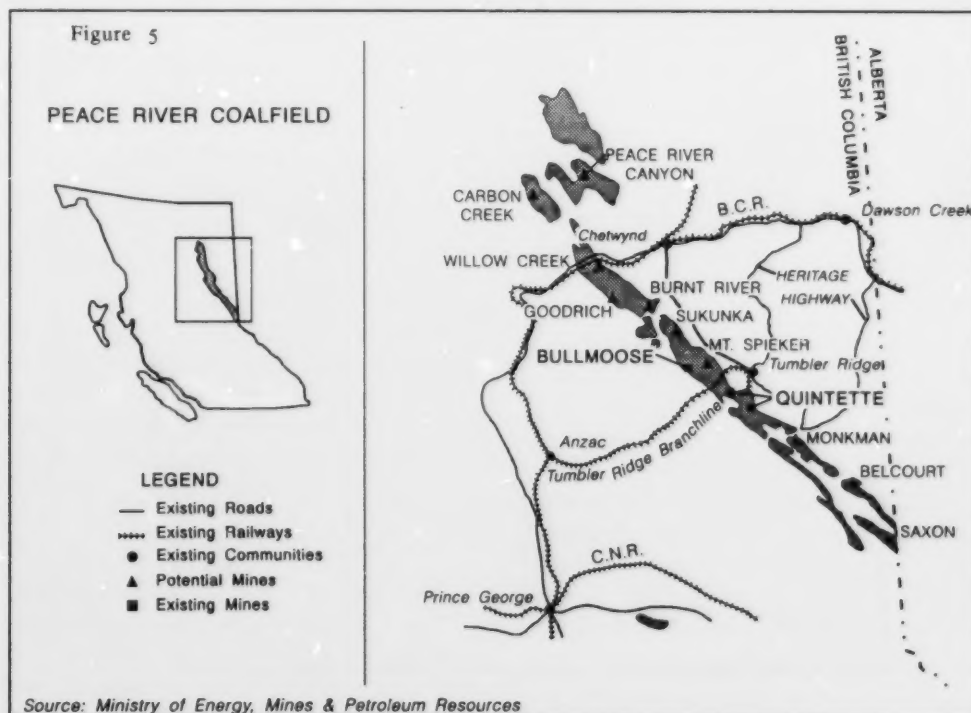
Historical

Coal was first noted along the Peace River in 1793 by Alexander McKenzie but these deposits remained dormant until the Alaska Highway was constructed in 1944. By 1950 three small mines were producing approximately 12 thousand tonnes per year. This early phase of mining lasted only a few years before the demand for this coal was displaced by petroleum. Total production during this time did not exceed 65 thousand tonnes.

Renewed interest in the coalfield began in 1969 with the development of the Japanese coking coal export market in the Crowsnest Coalfield. Intensive exploration activity between 1969 and present has resulted in virtually all potential coal horizons being examined often by several different companies.

Geology

Coal deposit locations in the Peace River coalfield are illustrated in Figure 5. These coals occupy a stratigraphic interval of over 3000 metres and are found in four different formations. Lower Cretaceous Gething and Gates formations contain the major coal measures of the region (Figure 6). Minor coal occurrences have also been investigated by exploration companies in the Jurassic-Cretaceous Minnes Group and in the Upper Cretaceous Wapiti Formation. The Peace River coalfield proper occurs in the inner Foothills of the Rocky Mountains from north of the Peace River south to the Alberta-British Columbia border. Coals of the Wapiti Formation are not in what has been traditionally known as the Peace River coalfield, but occur in the closely associated outer Foothills and Alberta Syncline structural zone. Folding and faulting are common within the coal deposits of the belt. Structural complications within deposits may range from simple to extreme, depending on the situation. In some locations multiple fault repeats have substantially increased seam thickness. Coals in the Wapiti Formation are relatively unaffected by structural complications and are generally flat laying. All major coals in the coalfield are closely associated with marine shorelines and within any



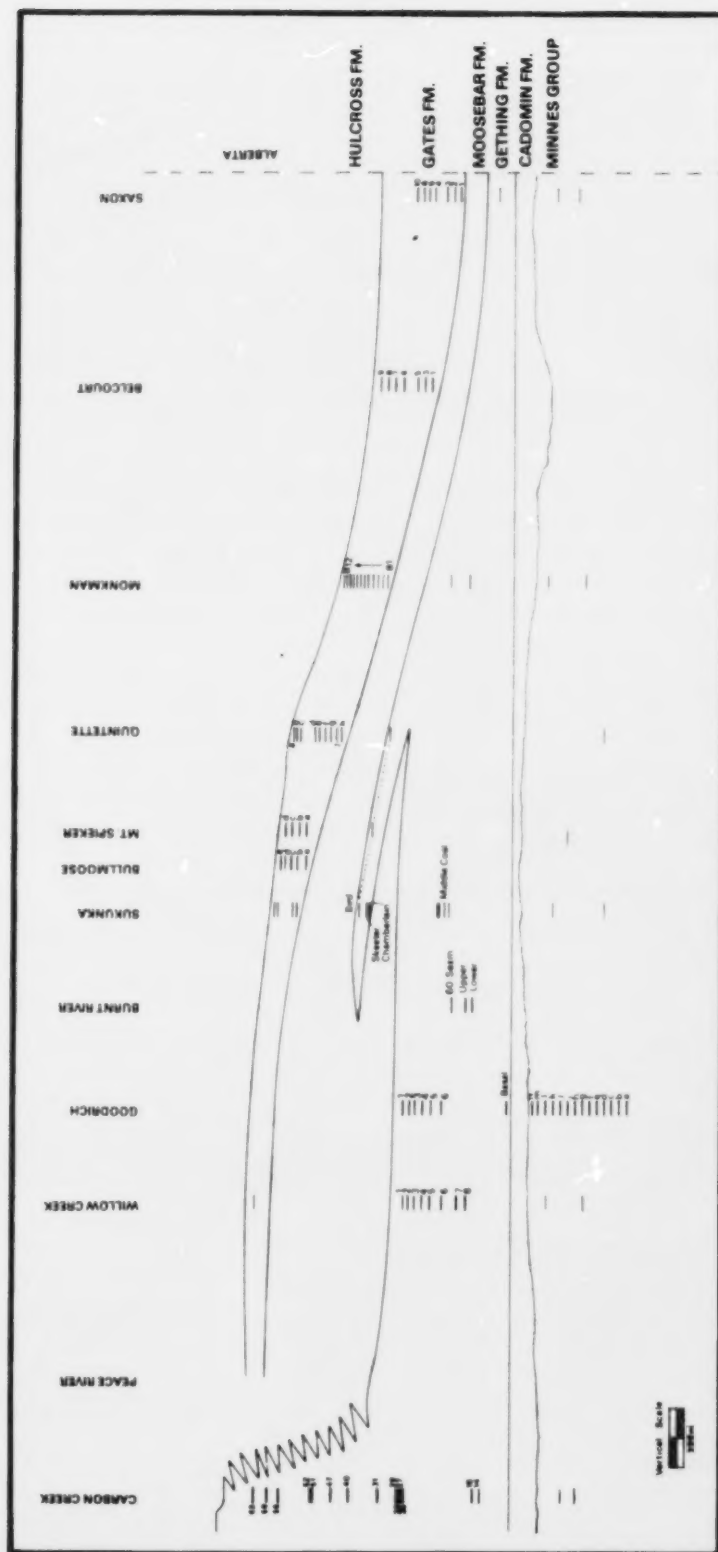


Figure 6: Schematic cross section of the Peace River coalfield showing stratigraphic relationships and relative coal seam positions. The Wapiti Formation is approximately 2000 metres above the top of the Gates Formation.

formation the marine influence on coal seams may vary with stratigraphic or lateral position.

Current coal production in the coalfield is from the Gates Formation. Coals of this interval are usually thick and continuous. They form the major coal resource of the coalfield from the Bullmoose area south to the Alberta border. Formation thickness decreases from about 350 metres at the Alberta border to about 60 metres at Peace River. Important coal seams are present in the formation from the south to just north of the Bullmoose mine where they thin and the formation becomes mainly marine in origin and non-coalbearing.

Gething Formation coals form a significant portion of the resource base of the coalfield. Minor past production has occurred from this formation but at present it is not a producer. Formational thickness varies significantly from about 100 metres in the south at the Alberta-British Columbia border to over 1000 metres in the north at Carbon Creek. In the Sukunka to Quintette region an upper member of the Gething Formation contains several major coal seams. This member pinches out just north of the Sukunka deposit. North of Sukunka the coals are located in the main body of the Gething Formation with major coal development being near the top of this unit. At Carbon Creek more than 100 coal seams have been identified with 10 seams being over 1 metre in thickness.

Minnes Group coals are present throughout the coalfield but have not proved as economically interesting as those in the Gates and Gething formations. Wapiti Formation coal occurs principally at the base of the formation where seam thickness may reach 2 metres.

Reserves and Resources

The coal reserves and resources of the Peace River Coalfield are large. The resource base for the coalfield is about 9.2 billion tonnes of coal in the ground (Table 4). The reserve base, that coal which could technically be produced at present and is known with some certainty is about 1.3 billion tonnes (Table 5).

Producers

At present two mines are producing from four pits in the Peace River Coalfield. The Bullmoose Mine is producing from the South Fork Pit while at Quintette production is from the Mesa, Wolverine and Shikano pits. At both mines addi-

Property	Measured	Indicated (million tonnes)	Inferred
Saxon	25	250	250
Belcourt	40	800	220
Monkman	400	800	1480
Quintette	150	50	2100
Mt. Spieker	30	5	85
Bullmoose			
& Sukunka	245	155	370
Pine River	65	125	395
Carbon Creek	50	30	35
Peace River	10	70	510
Butler Ridge			450
Halfway River			75

Property	Proven	Probable (million tonnes)	Possible
Burnt River	15.0	15.0	
Sukunka	179.0		
Bullmoose			
South Fork	36.2		
West Fork		30.1	
Quintette			
Mesa	48.7		
Wolverine	56.8		
Shikano	20.9		
Babcock	68.0		
Quintette Trend	26.1		
Roman	26.5		
Monkman	94.0	127.6	23.0
Belcourt			840.0
Saxon	13.0		233.4
Carbon Creek	61.6		
Peace River Canyon			44.8
Mt. Spieker	32.7		
Goodrich			
Willow Creek		72.5	

Source: Preliminary Map 65.

tional pit areas are available for expansion when required. Last year Bullmoose produced 1.6 million tonnes and employed 336 people. Quintette produced 4.61 million tonnes and employed 1462 people.

Potential Producers

Many potentially economic deposits are located in the coalfield. Several have had test

mining and bulk sampling performed. Extensive mine planning and feasibility studies have been performed on several other deposits. The location of the Tumbler Ridge Branch line in-part dictated which of the deposits were originally developed. Both the Sukunka and the Monkman deposits would have been seriously considered for production had the railroad location been more favorable. The Burnt River deposit has been bulk sampled and holds excellent potential as a thermal coal source should the market situation change. These three deposits will likely be the next to be developed should the demand increase. The two producers also have extensive additional potential within their mine holdings. Deposits in the Pine Pass Valley have potential for small scale mines and the advantage of an existing railroad. These deposits have complex structure or require underground extraction. South of the Monkman deposit, the Belcourt and Saxon properties have a good resource base but due to their isolation are long term prospects at present. North of the Pine River deposits in the Gething Formation hold small scale development potential due to the thin nature of the seams and the likely requirement of underground mining.

INTERMONTANE ZONE

NORTHERN INTERMONTANE ZONE AND QUEEN CHARLOTTE ISLANDS

Geology

The stratigraphic nomenclature for north-west British Columbia is in a constant state of flux; Figure 7 indicates approximately how group and formation names are used in different areas.

Rocks of Mid-Jurassic or older age contain no coal with the exception of the Laberge Group. The Laberge Group and the overlying Tantalus

Table 7

Coal Rank	Total Resources (million tonnes)
Lignite to Sub Bituminous	150
High Volatile Bituminous	1 478
Medium to Low Volatile Bituminous	219
Anthracite	10 308
Total	12 155

Table 6

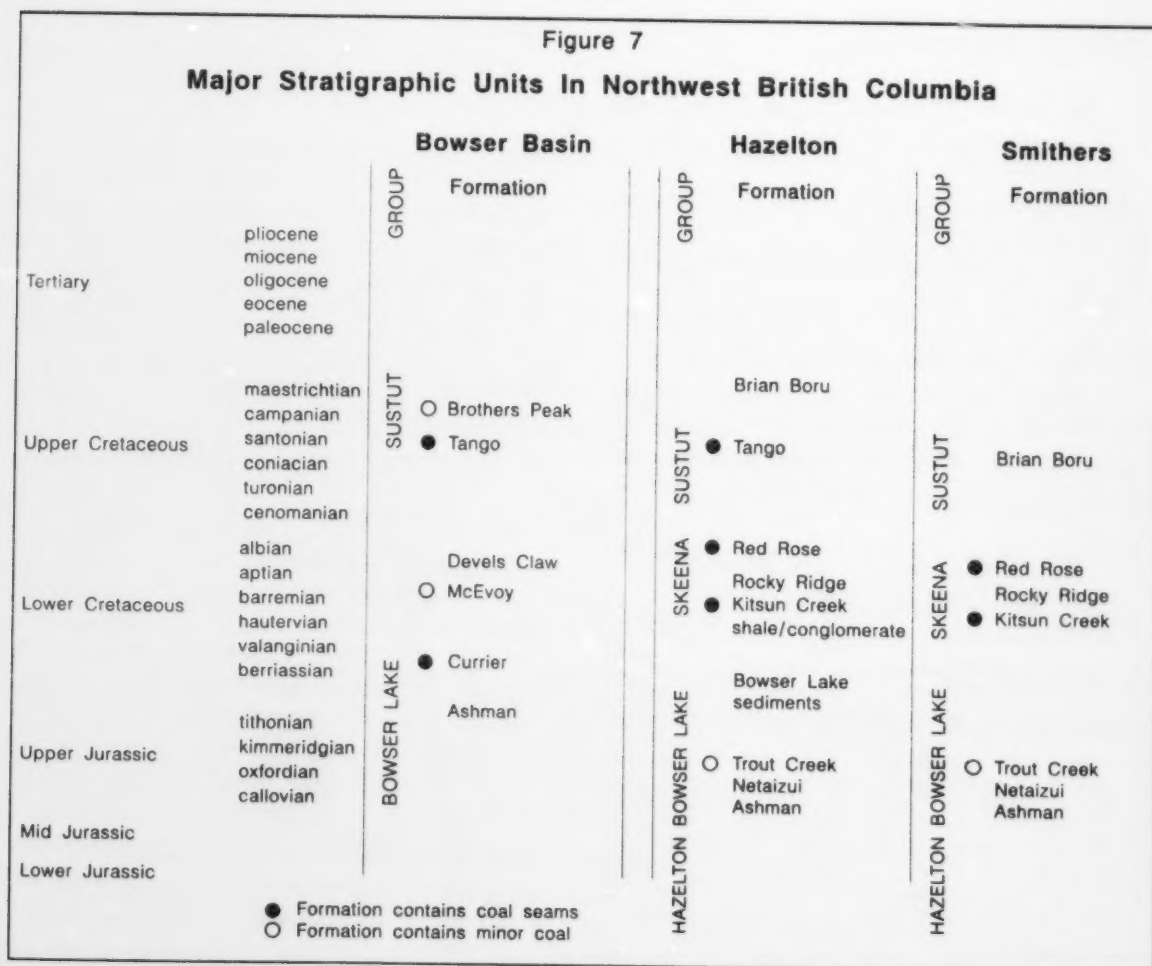
Summary of Resources and Reserves of Northwest B.C.

	Reserves			Resources	
	Measured		Probable	Possible	Speculative
Bowser Lake Group					
Klappan	0	86	100	487	5 620
Groundhog	0	0	0	240	3 760
other	0	0	0	0	10
Skeena Group					
Telkwa	25	25	180	300	200
Coal Creek					
(Zymoetz)	0	0	2	10	23
Deny's Cr.	0	0	0	0	20
Kathlyn L.	0	0	0	0	5
Sustut Group					
Sustut		0	0	63	107
Tertiary					
Tuya River	0	0	200	200	250
Coal River	0	0	0	0	101
Seaton	0	0	10	10	36
Queen Charlotte Islands					
	0	0	0	15	70
Totals	25	111	492	1 325	10 202
Total Resource					12 155

Northwest British Columbia Coal Basins and Prospects

1	Telkwa Basin	14	Thautil River
2	Coal Creek	15	Seaton Station
3	Denys Creek	16	Driftwood Canyon
4	Kitsegucla River	17	Tertiary QCI
5	Seely Lake	18	Jura-Cretaceous QCI
6	Kathlyn Lake	19	Klappan Basin
7	Evelyn Station	20	Groundhog Basin
8	Guess Creek	21	Sweeny Creek
9	Fireweed	22	North Sustut
10	Boucher Creek	23	South Sustut
11	Little Cedar River	24	Tuya River Basin
12	Skeena / Kispiox Rivers	25	Coal River Basin
13	Chisholm Lake	26	Rapid River Basin

Major Stratigraphic Units In Northwest British Columbia



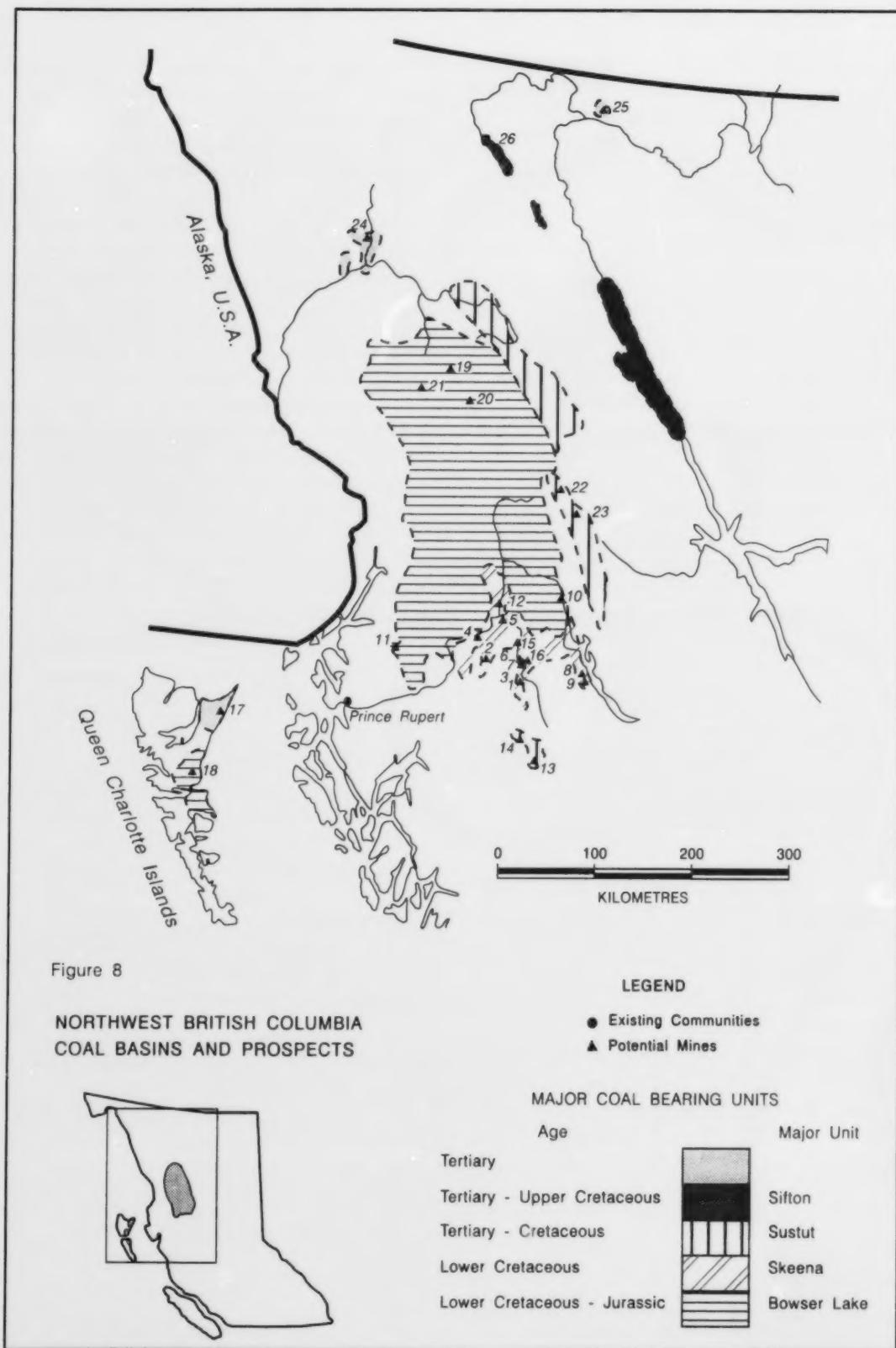


Figure 8

**NORTHWEST BRITISH COLUMBIA
COAL BASINS AND PROSPECTS**

Formation contain traces of coal. Generally pre Mid Jurassic rocks in northwest British Columbia are assigned to the Takla Group of Late Triassic age or the Hazelton Group of Early to Middle Jurassic age.

The Hazelton Group is composed mainly of island arc assemblages of basalts, rhyolites, tuffs and minor amounts of sediments. The group forms the basement for younger coal-bearing assemblages which are in order of decreasing age, Bowser Lake Group, Skeena Group, Sustut Group and Tertiary grabens.

The Bowser Lake Group outcrops extensively in northwest British Columbia, generally north of Smithers and east of Dease Lake (Figure 8). The group is a regressive sequence of marine mudstones, deltaic sandstones and siltstones, and non-marine mudstones, siltstones, sandstones and coal. In the north two major coal basins and a number of coal showings are identified in the Bowser Lake Group (Figure 8). Coal seams of the Klappan and Groundhog coal basins are assigned to the Currier Formation of Lowermost Cretaceous age.

The Skeena Group outcrops along the southern margin of the Bowser Lake Group (Figure 8). It has been divided into a number of formations; in some cases the nomenclature is not consistent from one map sheet to the next. Despite this the following generalization is reasonably accurate. The Kitsun Creek Formation which includes deltaic coal-bearing sediments is overlain successively by the Rocky Ridge Formation which is usually composed of volcanic rocks and by the Red Rose Formation which is non marine and coal-bearing.

The Sustut Group outcrops to the east of the Bowser Lake Group and rocks of the same age outcrop to the south of the Skeena Group (Figure 8). It is upper Cretaceous to Eocene in age. East of the Bowser Lake Group thin coal seams occur in the Tango Formation of the Sustut Group but most of the coal described on the coal licences in the area is in Bowser Lake rocks. South of the Skeena Basin thin coal seams are found in upper Cretaceous rocks in a number of places (Thautil Creek and Chisholm Lake showings (Figure 8)).

Coal occurs in Tertiary rocks in a number of locations in northwest British Columbia (Figure 8), often in grabens. The original size of these

basins is not known, faults defining the grabens may also have defined the limits of the basins or simply have allowed parts of larger basins to escape erosion. Sediments are non-marine and sandstone or conglomerate rich. The Tuya River and Coal River Basins contain a substantial coal resource, the Seaton Coal Basin less and the Driftwood Canyon and Rapid River Basins very little coal resource.

COAL IN THE BOWSER LAKE GROUP

The Bowser Basin Group is composed of over 4000 metres of non-marine and marine deformed sediments of Upper Jurassic to Lower Cretaceous age. The lowermost Jurassic Ashman Formation is composed of marine shales and shallow marine sandstones and is over 1000 metres thick. It is overlain by the Currier Formation composed of over 1000 metres of non-marine sandstone shales and coal seams. The base of the Currier may be as old as Late Jurassic or Earliest Cretaceous. The overlying McEvoy Formation is non-marine, sandier and contains fewer and thinner coal seams than the Currier. The Devil's Claw Formation which forms the top of the Bowser Basin Group is over 500 metres thick and is composed of sandstones and conglomerates. The Bowser Basin Group is unconformably overlain by the Upper Cretaceous Sustut Group.

Klappan Coal Basin

The Klappan coal basin is in the northern part of Bowser Basin (Figure 8). The area of economic interest within the Klappan coalfield is on the east limb of the Mt. Beimes synclorium which trends northwest.

Table 8

Klappan Coal Basin Resource (million tonnes)

Area	Reserve		Resource	
	Measured	Probable	Possible	Speculative
Lost Fox	74	75	85	765
Hobbit Broatch	12	25	370	730
Summit			32	1860
Nass				1990
Skeena				275
TOTAL			6293	

Table 9.
Quality of Raw Northern Intermontane and Queen Charlotte Island Coals
(as-received basis)

Area	Moisture	Ash	Volatiles	Fixed Carbon	Sulphur	Heating value
Klappan	1 - 2%	18 - 46	6 - 8		0.35 - 0.65	
Groundhog						
McEvoy	1.04 - 5.7	4 - 25.4	5.2 - 8.7	62	1.46 - .74	6786 - 7674 c/g
Beirnes	1.08 - 1.35	27 - 29	7.06 - 7.69	62 - 65		
Telfer	3.5 - 6.	21.8 - 34.1	4 - 13.3	46.7 - 70.7	.44 - 1.57	5200 - 6656 c/g
Guess Creek	24.03	37.26	16.52	22.18	.26	
1.6 SG	5.14	13.8	30.09	50.97	.61	
Lt. Cedar R.	3	15	4.2	77.2	.6	
Kispiox & Skeena R.	1.1 - 2.1	27.3 - 18.2	11.3 - 22.9	50 - 68.3		
Coal Creek (Zymoetz)	5.2	16.1	37.4	48.6	.47	7097 c/g
Denys Cr.	1.12	38.9				
1.6 SG	1.71	12.5	29.9	55.9	.92	6683 c/g
Kathlyn Lk.						
A	8	16.5	8.2	67.3		
B	13.9	11.2	9	65.9		
C	15.2	17.8	8.3	62.0	.1	5667 c/g
Sustut North		37.2				
1.5 SG	1.65	8.37	18.3	71.6	.55	7483
Chisholm	2.35	18	26.7	53.2		
Thautil R.	10.8	9.4	31.2	48.8		
Tuya River	12.4	19.1	30.7	37.8	.5	6663
Coal River						
A	8.1	6.7	53.4	31.8	.34	5264
B	15.4	6.2	45.6	32.6	.3	4983
Seaton	3.65	29.3	19.0	48.1	1.37	8270
Driftwood	7.6	23	34.3		35.1	
Queen Charlotte Islands						
Tertiary	18.5	2.6	44.2	34.7		
Jura-Cretaceous coals						
Wilson C.	1.9	17.1	32.8	48.2	.9	
Falls Cr.	1.1	27.2	26.1	45.6	.7	
Slatechuch	5.1	16.0	5.3	73.6	.6	

Reserves and Resources

Reserve calculations and resource estimates exist for the Gulf Canada Corporation licence block. A number of areas within the licence block have resource potential as indicated in the Table 8.

Mine plans in the Lost Fox area outline about 30 million tonnes of product coal. This can be considered a measured reserve with some reservations about the economics.

History of Production

Coal was first discovered on the Klappan property in 1899 and there has been exploration activity in the area up to the present. There has been no active mining in the area though Gulf Canada Corporation mined over 200 000 tonnes from a test pit and adits. Trial cargoes totalling 98 500 tonnes were shipped from Stewart to potential customers in eastern Canada, Europe and Korea.

Quality

Klappan coal is low volatile to anthracite in rank. Averaged analytical data is presented in Table 9.

Groundhog Coal Basin

This is the southern part of the area previously referred to as Groundhog Coal Basin. The northern part is now called the Klappan Coal Basin. Rocks in this part of the Bowser Basin are mainly non-marine Jura-Cretaceous sandstones, siltstones and shales of the Currier Formation. Folds trend northwest. Folding is intense in some areas with folds overturned to the northeast and thrust faulted. Coal formed in fresh water swamps and was occasionally inundated by marine transgressions. Exploration has taken place in at least five areas within the Groundhog Coal Basin these areas are; McEvoy Flats, Mt Jackson, Panorama Mountain, Beirnes Creek, and Telfer Creek.

Reserves and Resources

An estimate of the total resource is 4 billion tonnes. The only area that has been appraised in detail is Panorama Mountain where a local resource of 240 million tonnes is estimated.

Exploration areas

Exploration holes in McEvoy Flats intersected several coal seams. One area may have surface mineable coal but no resource or reserve numbers are given. Between 1904 and 1911, two tunnels were driven to bulk sample coal on Discovery Creek.

An old report from the Mt Jackson area mentions a regional resource estimate of 4 billion tonnes; details are not given of how this number was derived. No quality data is available.

The Panorama Mountain property was mapped in detail in 1980 and 1981. A resource estimate of 240 million tonnes is provided. The coal is anthracite with reflectances ranging from 2.7 per cent to 4.0 per cent.

Coal in the Beirnes and Telfer Creek areas is anthracite as indicated by the analytical data in Table 9.

COAL PROSPECTS

A number of coal showings in rocks tentatively assigned to the Bowser Lake Group are located outside the limits of the Klappan and Groundhog Coal Basins.

Guess Creek

The showing is south of Fulton Lake (Figure 8). Rocks are dated by macro-fossils and palynology as Middle Jurassic (Callovian) and probably part of the Trout Creek Formation. Beds are steeply dipping and intruded by dykes and sills. Greywackes mudstones and a chert pebble conglomerate outcrop.

The coal ranges in rank from high volatile bituminous to meta anthracite, and contains a variable but generally high percentage ash. Up to five seams outcrop; thicknesses are variable and faulting and folding complicate any interpretation. One coal zone is tentatively mapped for a strike length of about 200 metres. It is up to 10 metres thick and contains up to 5 metres of high ash coal.

Quality

Seams are generally high in ash and contain many rock splits. Quality information is summarized in Table 9.

Coal rank is variable but averages high volatile bituminous. The coal has high organic sulphur and does not wash well.

Reserves and Resources

A speculative resource of 10 million tonnes of coal and carbonaceous shale exists in the area.

Boucher Creek

The showing is 105 kilometres northeast of Smithers (Figure 8) and is in Upper Jurassic rocks of the Bowser Lake Group. A carbonaceous unit up to 30 metres thick contains "coal seams" which are generally a metre or less thick. Seven coal-sample analyses are reported, all the ash concentrations are greater than 65 per cent indicating that no coal was sampled. No further assessment of this showing was made.

Sweeney Creek

The showing is at the headwaters of Konigus Creek 40 kilometres east of highway 37 and 240 kilometres northwest of Hazelton (Figure 8). It is within rocks of the Bowser Lake Group. Twenty coal seams all less than 1 metre thick were identified. They are generally high in ash and the rank is anthracite (reflectance values range from 2.57 to 3.24 per cent). No resource estimate is attempted. The property was staked and held for 2 years in the 1980s by Esso Resources Ltd., and then dropped.

Little Cedar River

The showing is 50 kilometres north of Terrace and west of the Kitsumkalum River Valley. Anthracite was first reported in the area in 1914 in rocks assigned to the Bowser Lake Group. The showing is on the western edge of the Bowser Basin and rocks in the area may have been metamorphosed by the Coast Range Intrusive Complex. A 1914 report describes a number of seams of anthracite up to 2 metres thick.

Average quality from the 1914 report is in Table 9.

Reserves and Resources

Because recent work has failed to locate the seams described in 1914, no resource estimation is attempted.

Kispiox and Skeena Rivers

A number of coal showings exist on the Skeena and Kispiox Rivers above their junction (Figure 8). Rocks in the area are assigned to the Bowser Lake Group. Coal showings are widely distributed and seams are generally thinner than 1.5 metres. Work in the area dates back to 1915; short adits and trenches were dug in the early 1900s but there is no mention of any mining. The area has received little attention in the 1980s.

No resource estimate is attempted, if there is a coal resource in the area it is obscured by valley fill.

Rank appears to vary from bituminous to semi-anthracite. Quality data averaged from old reports is listed in Table 9.

Cedar Creek

Coal is reported to occur in Cedar or Coyote Creek two kilometres south of Hazelton. There is uncertainty about the exact location and little data could be located.

COAL IN THE SKEENA GROUP

Telkwa Coal Basin

The Telkwa coal basin is located 15 kilometres south of Smithers B.C., is centered on the confluence of the Telkwa River and Goathorn Creek (Figure 8) and is approximately 30 by 15 kilometres in size. Rocks in the basin are part of the Lower Cretaceous Skeena Group and belong to the Red Rose Formation and possible in part to the older Kitsun Creek Formation.

Coal has been located in outcrop and drill holes north of the Telkwa River, on the west and east side of Goathorn Creek, and at the headwaters of Tennes and Cabinet Creeks.

Reserves and resources

A preliminary estimate of the total resource of the coal basin is 730 million tonnes. Detailed surface mineable reserve estimates have been made by Crows Nest Resources, in summary there is an in-situ measured mineable reserve of 25 million tonnes and an additional measured resource of 25 million tonnes. The reserve and resource data for the basin is depicted in Table 9.

History of Production

Old mines were adjacent to the Telkwa River and Goathorn Creek. They were underground room and pillar mines with drifts down the full dip of the coal beds and horizontal crosscuts along the strike. Faults and methane were constant problems.

Coal Quality

All coal mined was used locally in north-west British Columbia for heating. Telkwa coal has been tested for coke making potential; coal from some seams does make a high-sulphur weak coke but mining and washing the coal for this purpose has never been seriously considered.

Telkwa coal is high volatile A bituminous; rank is locally increased by dykes and a Tertiary intrusion. There is one report (circa 1910) of an adit in Goathorn Creek that encountered anthracite but drilling in the Goathorn Creek area has not located extensive areas of coal with a rank above that of high volatile A bituminous.

In the Cabinet Creek area south of Goathorn Creek mean maximum reflectances average 2.33 per cent indicating a rank of semi-anthracite. Mean maximum reflectance values for coal from Units 1 and 3 in all other areas generally range from .7 to 1.0 per cent and average .84 per cent.

Raw ash for coal from all seams except Seam 1 averages about 20 per cent. Coal from seam 1 averages about 30 per cent ash. Average raw sulphur content ranges from .87 to 3.0 per cent. The quality of a blended and washed Unit 3 coal is reported in table 10.

Table 10		
Average Coal Quality Telkwa Coal Basin		
	As Received Basis	Air Dried Basis
Product moisture	10.0	1.5 +/- 0.5
Ash %	11.0	12.0 +/- 1.0
VM %	25.0	31.0 +/- 1.0
S %	1.0	1.1 +/- 1.0
CV Cals/gm	6550.0	7250.0
General product data		
Blended Clean Coal sulphur estimated at 2.0 lbs./10 ⁶ BTU		
fuel ratio 1.8 to 2.2		
HGI 60		
Ash fusion Temp IDT (reducing) 1270 - 1310° C		
Basicity Index 0.15 - 0.25		
Trace and ultimate data		
Hydrogen % 4.5		
Nitrogen % 1.2		
Chloride % .01		

COAL PROSPECTS IN THE KITSUN CREEK FORMATION

There are a number of coal prospects in Skeena Group rocks. Generally exact ages of the prospects are not known but based on stratigraphy they are assigned to either the Kitsun Creek

Formation or the Red Rose Formation. Coal prospects assigned to the Kitsun Creek Formation include Fireweed, Coal Creek Denys Creek and Kitseguecla River.

Coal Creek

(tributary to Zymoetz River)

The property is located at the confluence of the Zymoetz River and Coal Creek; 50 kilometres west of Smithers (Figure 8). Sediments in the area are likely Cretaceous in age. Sandstones and chert-pebble conglomerates contain coal seams ranging in thickness up to 5 metres. Rocks dip moderately to the northwest and are faulted rather than folded. The Basin is about 5 x 5 kilometres in size.

History

The area was first staked in 1908. Exploration activity (adits and drilling) took place in the period 1908 to 1929. The area was mapped in 1929 and more recently in the period 1969 to 1985. No mining has taken place and there are no reports of test shipments.

Reserves and Resource

A resource of about 35 million tonnes probably exists in the Basin though recent drilling delineated only about 1 million tonnes as surface mineable. A tentative resource breakdown is presented in Table 6.

Quality

The coal is a high volatile bituminous thermal coal with some agglomerating properties. Average quality is presented in Table 9.

Denys Creek

The showing is located on Denys Creek north of its confluence with Thautil River and about 35 kilometres southwest of Telkwa (Figure 8). Old literature (circa 1915) refers to Denys Creek as Goldstream Creek and describes 3 drill holes which intersected 4 seams with thicknesses ranging up to 3 metres. The property was explored again in the 1980 to 1984 period when 3 holes were drilled which did not intersect economic thicknesses of coal. The coal bearing rocks are faulted and folded and occur in a basin 2 x 4 kilometres in size. Sediments are sandstones and mudstones with a basal conglomerate resting

unconformably on Hazelton Group volcanics. The sediments have not been dated by fossils but are presumed to be Lower Cretaceous.

Reserves and Resources

No estimate of resources have been made; for the propose of this report a speculative resource of 20 million tonnes is used.

Quality

Coal is high volatile bituminous in rank and has weak agglomerating properties. Average quality from the three 1980-1984 period drill holes is provided in Table 9.

Fireweed

The fireweed property is 54 kilometres east-northeast of Smithers on the west shore of Babine Lake. There is very little outcrop in the area but sediments underlying the property are assumed to be part of the Kitsun Creek Formation. Extensive drilling following initial prospecting and a geophysical program has outlined zones of disseminated sulfides. Drilling of one of the geophysical anomalies on the western edge of the property intersected coal. One hole intersected 48.55 metres of carbonaceous mudstone and coal over 68.54 metres. Rocks appear to be steeply dipping and based on the core-bedding angles the true thickness of carbonaceous mudstone and coal is approximately 31 metres.

No quality data exists yet but core-logging results indicate that probably not more than 5 metres true thickness of the intersection is coal. The drill spacing is too large to permit tracing of the coal zone; its extent is certainly not tested and no resource estimate is attempted.

This prospect is interesting in that it extends the area of coal-bearing Kitsun Creek rocks to the east from present known prospects.

Kitsegucla River

The showing is located 25 kilometres southwest of Hazelton and 10 kilometres up the Kitsegucla River from its confluence with the Skeena River (Figure 8). Rocks in the area are tentatively mapped as part of the Skeena Group. The showing is described in the 1900s but no

recent data exists and a preliminary attempt to locate the showing in 1990 was unsuccessful. Coal-bearing sediments do outcrop close to the confluence of the Kitsegucla and Skeena Rivers. Sediments are sandstones mudstones containing numerous plant fragments and carbonaceous zones. No quality data exists and no resource evaluation is attempted.

COAL PROSPECTS IN THE RED ROSE FORMATION

A number of Skeena Group coal prospects are assigned to the Albian Red Rose Formation. These include the Seely Lake Kathlyn Lake Evelyn Station, Cedar Creek, Kitsegucla River, and Kispiox and Skeena Rivers.

Seeley Lake

The showing is located 5 kilometres southwest of Hazelton adjacent to highway 16 (Figure 8). It was found by chance in 1981 while the area was being explored for base metals. Since then 20 holes have been drilled and a number of seams of anthracite intersected. Thicknesses range up to 1.5 metres and aggregate coal thickness reaches 12 metres. The sedimentary section is composed of sandstones, mudstones and conglomerate metamorphosed by a nearby intrusion.

There has been no bulk sampling or mining in the area and no quality data could be located. No resource estimate exists and none is attempted.

Kathlyn Lake

The showing is located 7 kilometres northwest of Smithers on the east flank of Hudson Bay Mountain (Figure 8). Coal was described in the area as early as 1915. The property was staked in 1917 and crosscuts and adits driven. Some mining took place in the period 1932 to 1936; probably less than 5 000 tonnes were mined.

Sediments in the area are mapped as part of the Red Rose Formation Skeena Group, and consist of thermally metamorphosed mudstones, siltstones and minor amounts of conglomerate. Twenty seams are described in 183 metres of section but only 1 is thicker than 1 metre. Beds are steeply dipping and probably folded.

No resource data exists for this property, a speculative resource of 5 million tonnes is estimated.

Average quality from old reports is presented in Table 9.

The coal is anthracite but moisture content is high. It is not clear if samples are oxidized or if the high moisture content is a result of the thermal metamorphism. Some of the coal has a graphitic appearance.

Evelyn Station

A small area of Red Rose Formation rocks outcrops in the lower reaches of an unnamed creek 18 kilometres northwest of Smithers. At least 10 seams ranging in thickness up to 0.50 metres were located in rocks similar to unit 3 at Telkwa. To date no coal quality data exists and no resource evaluation has been attempted.

COAL IN THE SUSTUT GROUP

The Upper Cretaceous to Tertiary Sustut Group unconformably overlies the Bowser Lake Group along its eastern margin. Coal is found in deformed Bowser Lake Group and in the overlying less deformed Sustut Group. Coal was first reported in the area in 1948 at Bear Lake which is approximately 170 kilometres north-northeast of Smithers (Figure 8).

North Sustut Property

Gulf Canada Ltd. looked at licences 40 kilometres north of Bear Lake (Figure 8). The Bowser Lake Group in the area was subdivided into three informal units. Coal is found in the middle unit which is 300 metres thick and contains clastic deltaic sediments. The coal is restricted to two zones, the upper zone contains 5.5 metres of coal over 14 metres of section and the lower zone 3.8 metres of coal over 6.6 m of section. Both zones are intensely folded and appear to be limited in both down dip and along strike direction.

Gulf Canada Ltd. estimated a possible resource of 63 million tonnes based on surface trenching and mapping.

Quality

Average Quality data from Trenches is listed in Table 9.

Coal rank is low volatile bituminous. Because all samples were oxidized there is no data on agglomerating properties.

South Sustut Property

Suncor held licences 10 kilometres north of Bear Lake (Figure 8) from 1982 to 1984. Coal was first discovered in the area in 1912 near Saiya Lake but there had been no detailed exploration for coal prior to 1982. Suncor drilled a total of 17 holes before relinquishing the property. The Bowser Lake Group in the area is tightly folded with folds trending northwest and beds dipping steeply. The coal in the Bowser Lake Group is restricted to the middle part of the section and appears to be underlain by the Ashman Formation. Seams are up to 9 metres thick. The overlying Sustut Group is subdivided into the lower coal bearing Tango Formation and the upper coal-poor Brothers Peak Formation.

Most of the Suncor exploration concentrated on the Bowser Lake Group coals of Late Jurassic age and high to medium volatile bituminous rank. Nine seams ranging up to 9 metres thick were located. Two seams were mapped in the Sustut Group. The rank of these seams varied from sub-bituminous to high volatile A bituminous.

Reserves and Resources

Suncor estimated a speculative resource of 200 million tonnes in 1982. Drilling in 1984 appears to have decreased this estimate though no number is given in the 1984 report. A speculative resource of 100 million tonnes is proposed pending more study of the 1984 exploration data.

Coal Quality

Seams contain moderate to high concentrations of ash and clean to 0.45 to 0.97 per cent sulphur. Mean Maximum reflectance measurements range from 0.51 to 1.47 per cent indicating a rank of medium to high volatile bituminous.

Chisholm Lake Prospect

The showing is 60 kilometres southwest of Telkwa on the north bank of the Morice River (Figure 8). Coal was first discovered in the area in 1909 when a single 2 metre thick seam was described. Exploration in 1979 to 1982 failed to locate significant coal. A single 1.5 metre coal

seam dips shallowly eastward in a sedimentary basin approximately 1 x 2 kilometres in size. The sediments (sandstones, mudstones and conglomerates) are dated as latest Albian to earliest Cenomanian. This is younger than the Telkwa Coal Basin.

Reserves and Resources

The basin is poorly defined. A conservative estimate using a 1.5 metre of coal seam underlying a basin of 1 x 2 kilometres size provides a speculative resource of 2 million tonnes.

Coal Quality

Average quality is reported in Table 9. The coal rank appears to be high volatile bituminous.

Thautil River Prospect

The showing is approximately 60 kilometres southwest of Smithers and is located in the valley of the south flowing Thautil River above its confluence with the Morice River (Figure 8). Coal was found in the area in 1910 and there is a report of 2 holes being drilled. Two coal seams each thicker than 1 metre were found east of the Thautil River in 1915. No further exploration took place in the area until 1979. In the period 1979 to 1981 four holes were drilled.

The basin is about 2 x 13 kilometres in size. Sedimentary rocks form a broad north trending syncline with dips generally less than 45°. The sediments which consist of a basal conglomerate fining upwards into sandstone and mudstone are dated as Upper Cretaceous to Eocene.

Reserves and Resources

The drilling in the period 1979 to 1981 failed to locate any coal; a single 1.5 metre coal seam was trenched. Coal could exist at the base of the sedimentary section in areas not penetrated by the drilling. No resource estimate exists. A speculative resource of 5 million tonnes is used for this report.

Quality

A single analysis performed in 1915 on oxidized coal is reported in Table 9. The rank appears to be high volatile bituminous.

COAL IN TERTIARY ROCKS

There are a number of Late Cretaceous to Tertiary sedimentary basins in northern B.C. Most are fault bounded and largely covered by alluvium. The basins have received little attention because of their poor exposure and or isolated locations. The major basins are the Sifton and Liard. The major coal occurrence in the Sifton Basin is in the Rapid River valley, and that of the Liard Basin is in the Coal River valley. Other important basins are Tuya River and Seaton. Rank ranges from lignite at Coal River to low volatile bituminous in part of the Seaton Coal Basin. As a group they represent the least explored coal resource of the area, probably because most of the basins are isolated and contain low rank thermal coal.

Tuya River Coal Basin

The Tuya River Coal Basin is about 40 kilometres west of Dease Lake (Figure 8). The Tuya and other rivers have cut into plateau topography with little outcrop to expose an ill-defined Tertiary coal basin at least 150 square kilometres in size. The basin is overlain by recent basalts to the north and thick alluvium to the south; the east and west contacts are fault bounded. A subsidiary basin or extension of the Tuya River Basin outcrops in the lower reaches of the Tahltan River. Seams are generally thinner with the exception of a single seam which is in excess of 2 metres thick.

At Tuya River the Tertiary sediments are poorly consolidated sands conglomerates and mudstones; a coal zone occurs low in the section; higher in the section conglomerates with volcanic clasts are abundant.

Reserves and Resources

About 200 million tonnes are surface mineable based on surface mapping and 3 drill holes which intersect the coal zone. The whole basin contains a resource in excess of 650 million tonnes.

Quality

Sixteen mean maximum reflectance measurements average 0.72 per cent. Average drill core coal quality is reported in Table 9.

Data in Table 9 is compatible with an ASTM rank of high volatile bituminous C. The

petrographic data indicates a somewhat higher rank of high volatile bituminous A. The coal qualifies as a low sulphur thermal coal or source for coalbed methane. It is non-agglomerating. The presence of amber might add to its value.

Coal River Coal Basin

Lignite was first reported in the Coal River valley in 1891. In 1944 coal outcrops were located 10 kilometres up river from the confluence with the Liard River. The basin is about 5 kilometres by 15 kilometres and the lignite outcrop is at least 4.6 metres thick. Lignite has also been intersected in water holes drilled near where the Alaska Highway crosses Coal River. There has been no extensive exploration or mining in the basin and it appears that it has not been explored recently. No resource evaluation exists; a speculative resource of 100 million tonnes is used in this report.

Quality

Two analyses one (A) a 1989 G.S.B analysis the other (B) a 1944 G.S.C are reported in Table 9.

Seaton Coal Basin

The Hazelton Group basement in the Telkwa, Smithers and Hazelton areas is extensively block faulted by Late Tertiary faults trending north-northwest. Cretaceous Skeena Group sediments survive in some down faulted blocks and in others along the Bulkley River valley there are outcrops of Tertiary sediments, some with coal. Because of alluvium in the valley it is difficult to know the extent of the individual "basins". Tertiary outcrops are found near Seaton Station and Moricetown in the Bulkley valley and in Driftwood Canyon.

The Seaton Coal Basin (also referred to as Seton) is located in the Bulkley River valley 24 kilometres south of Hazelton (Figure 8). Previous literature has described the basin as Jura-Cretaceous but recent palynology dates it as Paleocene. Coal rank is high to low volatile bituminous (high for a Tertiary coal basin) and the coal has good agglomerating properties and fluidity. Rocks are shallow dipping, poorly consolidated sandstones mudstones and conglomerates with numerous thin coal seams.

Reserves and Resources

Development work dates back to about 1916. Adits were constructed in the period 1916-1927 and a 40 ton test shipment excavated. No resource calculation could be located but based on using a thickness of 1.5 metres of coal in the section over 5 x 5 kilometres the resource could be up to 56 million tonnes. Based on trench and drill data the resource is classified in Table 6.

Tertiary sediments outcrop south and north of Moricetown on the banks of the Bulkley River. Rocks are poorly consolidated sandstones with coalspar, fossil tree trunks and seamlets of vitrain. No coal seams thicker than a few centimetres were located. A single reflectance measurement of 1.71 per cent was obtained from the coalspar. This may be influenced by nearby Tertiary intrusive rocks. No resource estimate is attempted.

Quality

Quality data derived from the G.S.B 1990 field season provides the average data in Table 9. Coal rank averages medium volatile bituminous. Mean maximum reflectance measurements range from 1.23 to 1.71 per cent and average 1.43 per cent.

Driftwood Canyon Coal Basin

The Driftwood Canyon basin, part of which is a provincial park, is 11 kilometres east of Smithers. Coal was first discovered in 1905 and claims were staked in 1914 but there has been no mining. The basin is at least 6.5 x 3.0 kilometres in size; beds are flat dipping faulted and intruded by dykes. Seams are generally less than 1 metre thick and lignite to high volatile B bituminous in rank. No resource calculation exists.

A mean maximum reflectance value of 0.65 per cent was obtained from a single sample. Average quality is reported in Table 9.

Rapid River Coal Basin

The coal showings are in a remnant of the Sifton Formation in the Rapid River valley 10 kilometres above its confluence with the Dease River (Figure 8). The Sifton Formation is Upper Cretaceous to Paleocene and is composed of conglomeratic sandstone, shale and minor coal. Detritus seems to have had an easterly source. The

Rapid River Basin is 16 x 5 kilometres in size and trends northwest. A number of reports mention thin seams up to 1 metre thick. There is little detail and apparently little quality information. A single analysis indicates a rank of high volatile B bituminous. There are no reports of extensive exploration. A 1947 report estimates an speculative resource of 1 million tonnes.

Laberge and Tantalus Basins

The Laberge Basin is made up mainly of Lower to Middle Jurassic marine sediments and outcrops to the north and northwest of the Bowser Lake Group (Figure 8). Some of the sediments are near shore facies and contain traces of coal. No significant coal showing are recorded.

The Late Cretaceous Tantalus Formation in part overlies unconformably the Jurassic Laberge Group and is composed of chert or quartz bearing conglomerate, sandstone, shale and coal. The coal is at the base of the formation and its existence is often inferred by the presence of float. Coal has been reported in 4 areas: Tagish Lake, Sloko River, Taku River and Inklin River. Information in all areas is very sparse, but there are reports of mining 1900 tonnes of coal from the Tantalus Formation in Yukon at Carmacks in 1967. No resource estimate is attempted for the coal showings in the Tantalus Basin in British Columbia. No quality data is available, references refer to float as lignite or in a single case as bituminous coal.

QUEEN CHARLOTTE ISLANDS

Coal occurrences on Queen Charlotte Islands are either Tertiary or Jura-Cretaceous and are restricted to the large northern island.

Tertiary Coal Prospects

Lignite is in the lower member of the Skonun Formation which underlies the northeastern portion of Graham Island. The Formation is poorly consolidated marine and non-marine sandstones shales and conglomerate of Miocene to Pliocene age; its thickness may exceed 2000 metres. The Tertiary basin can be divided into two sub-basins, the southern experienced less tectonism. In the northern basin at Skonun Point up to 13 seams with a cumulative thickness of 6 metres occur in 60 metres of section. They are folded into a west-plunging moderately appressed anticline.

Reserves and Resources

There are a number of showings of lignite and coal of higher rank which have been intersected by oil wells. No reserve calculations exist in the literature numbers range from 50 to 1000 million tonnes. The lower number of 50 million tonnes speculative resource is used in this report.

Coal Quality

Three analyses of the Tertiary coal provide average data listed in Table 9. The fixed carbon and volatile matter values indicate a rank of sub-bituminous to lignite. The ash content is low though it would be somewhat higher on a dry basis.

Jura-Cretaceous Prospects

The Jura-Cretaceous coals occur in the Yakoun, Queen Charlotte and Haida Formations, all of which are folded and faulted. Correlation of coal seams is difficult because coal exposures are scarce widely scattered and vegetation is thick. Resource estimates range from 35 TO 800 million tonnes; this report uses the lower number broken down as follows: 15 million tonnes of high volatile bituminous (possible resource), 10 million tonnes high volatile bituminous (speculative resource) and 10 million tonnes anthracite (speculative resource).

History of Production

Coal was first discovered in 1865. The Cowgitz Mine operated from about 1865 to 1872 and mined a few thousand tonnes. There were a number of shafts, adits, crosscuts, and test pits excavated over the years, but no large scale production.

Coal Quality

Coal quality data exists from a number of the old exploration camps; Wilson Creek, Falls Creek, and Slatechuck.

Coal from the Wilson Creek camp is high volatile B bituminous. Ash varies from 3 to 30 per cent. Some samples are weakly agglomerating.

Samples from Falls Creek have high ash contents; rank appears to be high volatile B bituminous (VM daf = 36 per cent. Some samples are weakly agglomerating.

Eleven analyses are available from Slatechuck; the low volatile content indicates a rank of anthracite. The coal is non-agglomerating. Average quality for the three areas is in Table 9.

SOUTHERN INTERMONTANE ZONE

THE CARIBOO DEPOSITS

The Cariboo coal measures occur in central B.C., immediately south of Quesnel, in an elongated basin of Tertiary sediments, bisected by the Fraser River. (Figure 9)

Geology and Coal Measures

These deposits occur in Eocene rocks which cover an area 40 kilometres north/south and up to 9 kilometres in width. The stratigraphic thickness is over 370 metres. The sediments are poorly consolidated and consist of conglomerate, sandstone, greywacke, shale and coal. The coalbeds intersected in drilling vary from 1.25 metres near surface to 22 metres at a depth of 148 metres. The sediments are gently folded about both north/south and east/west axes. Late Tertiary faults cut and partially bound the basin.

The coal varies in rank from sub-bituminous B to high volatile C (Table 11).

Exploration and Development

Sporadic exploration has occurred since 1920, but no coal has been produced.

Resources

Exploration has been conducted only over the southern portion of the basin, in which Hodson Creek (1000 metres x 160 metres) alone has had moderately close-spaced drilling, indicating 52.5×10^6 tonnes of coal, down to a depth of 80 metres below which a further 50×10^6 tonnes is inferred.

THE THOMPSON RIVER OCCURRENCES

The Tertiary deposits extend northwards from Kamloops along the Thompson River for almost 100 kilometres in the form of small isolated remnant basins, loosely grouped around Chu Chua to the north and near Kamloops to the south. (Figure 9)

Geology and the Coal Measures

The coal measures are about 200 metres thick and include conglomerate, arkose and shale, in places capped by younger volcanic rocks. The sediments are moderately folded along an axis parallel to the North Thompson River. Three coal zones occur in the measures from the upper zone of 4.7 metres to the middle zone of 2.3 metres down to the lower zone of a single seam of 1.1 metres.

The rank varies from sub-bituminous C to high volatile C (Table 11).

Production

2500 tonnes of clean coal were produced from 1920 to 1923.



Figure 9 Coal districts, coalfields and coal deposits of the southern Intermontane Region of British Columbia.

Resources

Due to the character of the occurrences, the coal and methane resources would in both cases amount to very little.

THE MERRITT COAL DEPOSITS

The coalfield is located 90 kilometres south of Kamloops in south central B.C. Two Tertiary deposits in the coalfield are known to contain coal. The Merritt area, encompassing the Town of Merritt, is approximately 60 km² in extent. The Quilchena area which lies 16 kilometres west of Merritt is about 40 km² in extent.

Geology and the Coal Measures

The sedimentary remnants consist of shale, sandstone, conglomerate and coal overlying volcanic rocks of the Nicola Group and in places are capped by younger volcanics. The sediments were subjected to severe folding and faulting resulting in the complex structure. (Figure 9)

QUILCHENA BASIN (northern portion)

Up to four coal zones occur in a 300 metre stratigraphic section. They vary up to 4.2 metres with a total coal thickness of 6.7 metres.

THE MERRITT BASIN (southern portion)

The seams are thicker and more numerous to the west of Cold Water Gulley which bisects the area. Here, seven seams, six of which are over 1.5

metres and vary to eight metres in thickness occur in a stratigraphic interval of 255 metres. The total coal thickness is 22.25 metres.

The coal is high volatile C to a bituminous in rank (Table 11).

Coal Production

2.7 x 10⁶ tonnes were produced from the area 1906 to 1946 with some very minor production in the 1960s 2 x 10⁶ tonnes of this was produced from the Coal Gulley Mines located west of the Cold Water River.

Resources

Of the 80 x 10⁶ tonnes inferred from exploration 70 x 10⁶ tonnes is from the Merritt coal basin. Most of the resource would have to be mined underground.

THE SIMILKAMEEN COAL DEPOSITS

These deposits are located at the southern end of the Interior Plateau in south central B.C. The village of Princeton encompassed by the coal basin is located 130 kilometres south of Kamloops and 170 kilometres east of Vancouver. The Tulameen basin is situated 10 kilometres west of Princeton. (Figure 9)

Geology and the Coal Measures

Tulameen, the elongated sedimentary basin 2 1/2 kilometres x 4 kilometres has a north/west axis and overlies younger Eocene volcanic rocks of the

Table 11.

Quality of Raw Southern Intermontane Coal (as-received basis)

Area	Moisture	Ash	Volatiles	Fixed Carbon	Sulphur	Heating value
Caraboo						
range	3.6 - 21.	.6 - 29.5	25.5 - 40.2	28.5 - 52.2	1.04 - 1.59	588 - 6977
average	13.5	15.4	32.2	39.1	1.3	6320
Thompson R.						
range	3.6 - 4.0	13.8 - 37.3	29.4 - 37.9	29.6 - 44.7		4572 - 6682
average	3.8	24.3	35.3	36.6		5739
Merritt						
range	2.7 - 7.7	4.4 - 28.6	27.8 - 37.8	38.9 - 55.1	.33 - .93	5688 - 7444
average	4.0	12.6	34.0	49.4	.6	6625
Tulameen	5.5	8.8	29	56.7	.6	6500
Princeton	16.2	7	30.8	46.2	.45	5611
Bowron R.	4.0	35.7	26.4	33.9	1.25	4444
Hat Creek	23.5	26.6	24.8	25.1	.4	3224

Princeton Group. The sedimentary sequence consists of three units, the middle of which is the coal bearing unit 140 metres thick, it consists of shale, siltstone, sandy shale and minor sandstone, coal and bentonite. The coal measures occupy the lower 75 kilometres of the unit. The four coal seams occur in a section varying in thickness from 21 metres to 37 metres. The upper three seams ranging from 2.1 metres to 3.7 metres are sufficiently close to form a single mineable coal zone. Little is known about the lowest seam. The Princeton basin, 4 kilometres x 7.25 kilometres overlies younger Eocene volcanic rocks. The sedimentary sequence conglomerate sandstone and shale interbedded with coal, carbonaceous siltstone and bentonite. Unlike the Tulameen basin, folding is complex. There is little evidence of faulting. Four different coal zones have been identified.

	Coal Zone	Zone Thickness (m)	Coal Thickness (m)
	1	3	2
Interval 105 m			
	2	26	7.6
Interval 198 m			
	3	30	
Interval 137 m			
	4	1?	
400 m			

Coal Quality

Rank is high volatile C to high volatile A in the case of Tulameen and lignite to sub-bituminous B in the case of Princeton (Table 11).

Production

Tulameen: From 1919 to 1940 and 1954, a total of 2.3×10^6 tonnes were produced.

Princeton: From 1909 to 1960, a total of 2.6×10^6 tonnes were produced intermittently from several small mines.

Table 12 documents the reserves and resources of the Tulameen and Princeton deposits.

BOWRON RIVER COAL DEPOSITS

The deposit is located in east central British Columbia, 50 kilometres east of Prince George,

Table 12

Coal Resources and Reserves Southern Intermontane Coal

	Reserves	Resources (million tonnes)
Princeton	20	220
Tulameen	—	110
Bowron	—	100
Hat Creek	566	4 700

along the Bowron River, and is situated within the Interior Plateau. (Figure 9)

Geology and Coal Measures

The coal measures occur in a north/west trending graben of Tertiary sediments bounded by Mississippian volcanics. It is about 25 kilometres long and 2.5 kilometres wide. A syncline has been postulated, but evidence of a monoclinical structure may be stronger. The sequence consists of siltstone, shale, sandstone and coal. The coal horizons occupy the lower 100 metres to 150 metres of the Tertiary sediments. Coal seams are local and discontinuous except for possibly the lower zone. The average reported thicknesses are; upper- 2.4 metres, middle- 3.4 metres and lower- 4.0 metres. The boundary faults trend north/west, minor sub-parallel faults occur. The average strike and dip of the sediments are $325^\circ - 330^\circ$ and 30° to 35° northeast.

Coal quality and resource information for the Bowron coalfield is contained in Tables 11 and 12 respectively.

HAT CREEK

The deposit is located 220 kilometres northeast of Vancouver and 80 kilometres west of Kamloops, in the southern intermontane region of British Columbia.

Geology and Coal Measures

The area is underlain by Tertiary volcanics and sediments. The coal measures occur in two grabens and vary from 350 metres to 550 metres in thickness. It consists of predominantly low rank coals and sediments ranging from classiness to conglomerate.

erates. The Hat Creek Formation is underlain by fluvial sediments and overlain by lacustrine sediments. The general structure is characterized by gentle open folds and block faulting.

The coal varies in rank from a lignite to sub-bituminous A (Table 11).

Production

The occurrence was reported by G.M. Dawson in 1877. Extensive exploration has taken place, but only a few hundred tonnes were produced from 1933 to 1942 for local consumption.

Resources

This is one of the world's thickest deposits of low rank coal. Drilling has delineated reserves of 566×10^6 tonnes and resources of 4700×10^6 tonnes. (Table 12)

INSULAR ZONE

VANCOUVER ISLAND COALFIELDS

Historical

Coals of Late Cretaceous age along the eastern coast of Vancouver Island have been

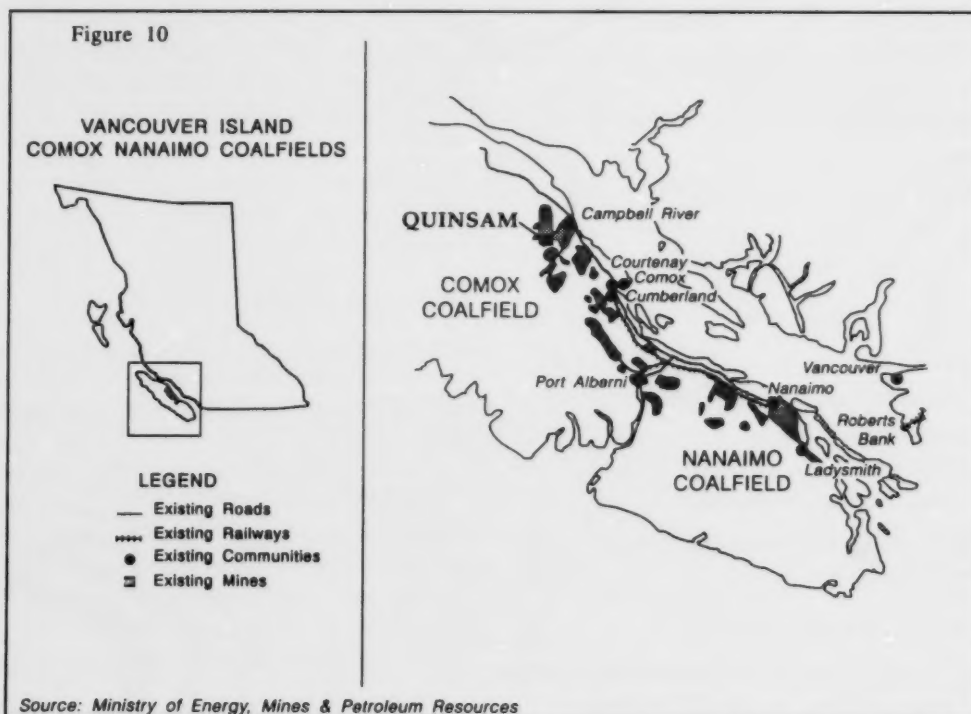
intensively prospected and mined from 1849 to the present day. Initial discoveries were made by local Natives, who reported coal showings at Nanaimo to the Hudson's Bay Company. Development was rapid and coal mining in the Comox and Nanaimo areas was a mainstay of the Vancouver Island economy until the early 1950s, when production began to decline rapidly. The lack of coal markets was caused by substitution of petroleum-based fuels in the railroad and shipping industries.

In the early 70s, oil prices were soaring and coal on Vancouver Island was again being considered as a useful commodity. The Quinsam mine in the Comox coalfield was a result of renewed exploration.

Geology

Coal on Vancouver Island occurs in two separate coalfields, the Comox coalfield in the north, and the Nanaimo coalfield in the south (Figure 10). All Vancouver Island coals are contained within the Upper Cretaceous Nanaimo Group, although the coals in the Nanaimo coalfield are younger than those of the Comox coalfield.

The structure of the Vancouver Island coalfields is characterized by gently warped and



tilted fault blocks. Most fault blocks are tilted and downthrown to the northeast along northwest-trending faults. Faults in the Nanaimo coalfield are more closely spaced and have greater displacement than those in the Comox coalfield.

Comox Coalfield

The Cumberland and Dunsmuir members of the Comox Formation host the coals of the Comox coalfield. Past and current production is from the Cumberland member only. Its characteristics are quite variable, although it generally contains from one to four coal seams or zones, with the thickest individual seam being about 3.5 metres thick. At the operating Quinsam coal mine, west of Campbell River (see figure 10), mining is in the No. 1 coal bed, 2.4 to 4.0 metres thick, in the basal Cumberland. Coals of the Dunsmuir tend to be thin.

Nanaimo Coalfield

In the Nanaimo coalfield coals are found in the Northfield member of the Extension Formation, the Newcastle member of the Pender Formation, and in the Reserve member of the Protection Formation. The Extension Formation hosts the Wellington and the Little Wellington (No.2) coal beds, which have average respective thicknesses of 2.5 and 0.5 metres. Both have contributed to coal production in the Nanaimo area. The Pender

Formation hosts the formerly productive Newcastle and Douglas coal beds. Their average thicknesses are 1.0 and 3.0 metres, respectively. There has been no production of coals from the Protection Formation.

Current Activity

At present there is one producing mine on Vancouver Island in the Comox basin. The Quinsam mine, owned and operated by Brinco Coal Corporation is working both surface and underground operations. Future plans involve development of three more pits. The mine is currently operating under a limited production permit of 1 million tonnes per year.

Coal Potential

Thermal and soft coking coal potential remains in both the Nanaimo and Comox coalfields. Proven reserves number 30 million tonnes in the Comox coalfield and 3 million tonnes in the Nanaimo coalfield. Potential resources in the Comox coalfield at the present time are estimated at 183 million tonnes, and 7 million tonnes in the Nanaimo area.

Detailed mapping and subsurface studies are currently in progress at the Ministry of Energy Mines and Petroleum Resources to further define the potential resource and determine possible economic deposits in these coalfields.

APPENDIX D.

Appendix D. BRITISH COLUMBIA'S DEVELOPMENT ASSESSMENT PROCESS

Background

Coordinated mine reviews date back from March, 1976, when the provincial Cabinet's Environment and Land Use Committee (ELUC) published the "Guidelines for Coal Development", and thus instituted a comprehensive review process for coal mining developments. In April 1979, the Ministry of Energy, Mines and Petroleum Resources published the "Procedures for Obtaining Approval of Metal Mine Development", thereby instituting the parallel Metal Mines Guidelines Review Process for hard rock mineral mining procedures, superseding them with the Mine Development Review Process (MDRP).

In July, 1990, the province of British Columbia introduced the Mine Development Assessment Act which formalizes the MDRP. Legislation was considered necessary:

- to demonstrate the province's commitment to thorough environmental assessments for all significant mine developments in British Columbia; and
- to establish a legal basis for public consultation in the review process by incorporating provisions for consultation.

The Act was proclaimed in the fall of 1991, establishing the Mine Development Assessment Process.

The Goals and Objectives of the Mine Development Assessment Process

The goal of the process is to facilitate and expedite technically sound, environmentally acceptable mining ventures in British Columbia by sponsoring and implementing a comprehensive, credible and widely understood procedure for project review and approval.

The objectives of the process are:

- To provide a "one window" contact point for mining proponents, government agencies and the public.
- To provide a staged information/consultation program which integrates environmental assessment and socio-economic factors in project planning and decision making.
- To provide a staged information/consultation program which integrates environmental assessment and socio-economic factors in project planning and decision making.
- To ensure the early identification and effective management of environmental and socio-economic factors in project planning and decision making.
- To integrate major policy and technical issues for decisions by the ministers of Energy, Mines and Petroleum Resources and Environment.
- To ensure that mine development complies with all applicable government policies, programs and regulatory requirements.
- To provide for joint reviews with the federal government and public consultation and mediation.

Stages in the Process

The review of proposed mine developments consist of the following stages:

Prospectus/Pre-Application

- Describes proposed mine project and identifies potential environmental and socio-economic impacts.

- Government agencies, local governments, native groups and the public review the prospectus and provide terms of reference for the company's application.

Application

- Contains project plans, an assessment of environmental and socio-economic impacts and proposed mitigation plans.
- Reviewed by federal and provincial government agencies, local governments, native groups and the public.
- Terms of reference may be provided for further studies to be conducted prior to a disposition decision.

Disposition Decision

Application may be:

- Accepted and a mine development certificate issued.
- Referred to an assessment panel, modified or rejected.

Mine Development Certificate

- Granted when all policy issues are resolved and all technical issues are known to be resolvable by affordable means.
- Decision is made by the ministers of Energy, Mines and Petroleum Resources and Environment.

Permits, Licenses and Approvals

- Permits, licenses and approvals necessary to construct, operate and reclaim a mine are only issued after a mine development certificate is granted.

Public Consultation

Specific public consultation programs are developed on a project-by-project basis as there is no single formula for meeting the needs of the public in all cases. The process provides opportunities for public input at all stages as follows:

- All mining company submissions are public documents and made available for review.
- Receipt of all applications is advertised in local papers.
- Copies are placed in public libraries of local communities and sent to provincial MLAs and federal MPs in whose ridings each project lies.
- Mining proponents are required to accommodate the review of submissions by the public and engage in public consultation at all stages prior to a disposition decision.
- Government review comments are, once compiled, available to members of the public upon request.

Panel Reviews

- The Ministers may direct a panel to engage in other forms of public consultation such as mediation, rather than public hearings.
- During panel reviews, independent technical experts may be hired by the panel and used by the public to assist them in reviewing a project.
- The panel's final report is made available to the public prior to the two ministers' disposition decision.

APPENDIX E.



Appendix E. GLOSSARY OF TERMS AND ABBREVIATIONS

afbc	– Atmospheric fluid bed combustion.	HT Winkler	– High Temperature Winkler.
AISI	– American Iron and Steel Institute.	IEA	– International Energy Agency.
BGL	– British Gas Lurgi.	IGCC	– Integrated gasification combined cycle.
btu/lb	– British thermal units per pound.	IGFC	– Integrated gasification fuel cell.
c.i.f.	– Cost insurance, freight.	IISI	– International Iron and Steel Institute.
CAC	– The Coal Association of Canada.	Joule	– 1055.06 BTUs
CEA	– Canadian Electrical Association.	kgs	– Kilograms.
CO₂	– Carbon dioxide.	lig-sub	– Lignite to sub-bituminous.
CV	– Calorific value.	lvb-an	– Low volatile bituminous to anthracite.
DOE	– United States Department of Energy.	m-lvb	– Medium to low volatile.
DRI	– Direct reduced iron.	MHD	– Magnehydrodynamics.
dwt	– Dead weight tonnes.	MJ/kg	– Mega joules per kilogram.
EEC	– European Economic Community.	MT	– Metric tonne.
EPRI	– Electric Power Research Institute.	NCA	– National Coal Association (U.S.A.)
FC%	– Coal fixed carbon content per cent.	ng/J	– Nanograms per joule.
f.o.b.	– Free on board vessel.	NO_x	– Oxides of nitrogen (nitrous oxide).
f.o.b.t.	– Free on board vessel trimmed.	NSRC	– Non-selective catalytic reduction.
GATT	– General agreement on tariffs and trade.	OECD	– Organization of Economic Cooperation and Development.
GT	– Gas turbine.	PCI	– Pulverized coal injection.
h-mvb	– High to medium volatile.	pfb	– Pressurized fluid bed combustion.
Hard Coal Equivalent – For the purposes of this report, world coal production and consumption has been shown in terms of "hard coal equivalent". This is calculated by converting coals of various heat rates (hard coals and lignites) to tonnes of oil equivalent and then factoring back to hard coal equivalent. One tonne of oil equivalent equals 1.5 tonnes hard coal and 3.0 tonnes of lignite.		S	– Sulphur.
HBI	– Hot briquetted iron.	SO₂	– Sulphur dioxide.
HGI	– Hardgrove grindability index.	SO_x	– Oxides of sulphur (sulphur oxide).
		SRC	– Selective catalytic reduction.
		Tonnes per worker	– The total annual production divided by the mine site work force for that year.
		USBM	– U.S. Bureau of Mines.
		VM% Volatile Matter	– Coal fixed carbon content per cent.

APPENDIX F.

Appendix F. COAL COMPANIES INTERVIEWED

- Brinco Coal Corporation
- Crows Nest Resources Limited
- Esso Resources Canada Limited
- Fording Coal Limited
- Luscar Ltd.
- Manalta Coal Ltd.
- Quintette Coal Limited.
- Smoky River Holdings Ltd.
- Teck Corporation
- Westar Mining Ltd.

APPENDIX G.

Appendix G. REFERENCES

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